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THE

OPERATIVE MECHANIC'S

WORKSHOP COMPANION,

AND

THE SCIENTIFIC GENTLEMAN'S

Practical Assistant:

COMPRISING

A GREAT VARIETY OF THE MOST USEFUL RULES IN
MECHANICAL SCIENCE,

DIVESTED OF MATHEMATICAL COMPLEXITY;

WITH

NUMEROUS TABLES OF PRACTICAL DATA AND CALCULATED RESULTS,
FOR FACILITATING MECHANICAL AND COMMERCIAL TRANSACTIONS.

BY W. TEMPLETON,
AUTHOR OF SEVERAL SCIENTIFIC WORKS.

FOURTH EDITION,

WITH THE ADDITION OF

MECHANICAL TABLES FOR THE USE OF OPERATIVE SMITHS,
MILLWRIGHTS, ENGINEERS, &c.

AND

PRACTICAL DIRECTIONS FOR THE SMELTING OF METALLIC ORES.

LONDON:
JOHN WEALE, HIGH HOLBORN.
1855.

187. c. 12.

LONDON:
BRADBURY AND EVANS, PRINTERS, WHITEFRIARS.

TO THE PUBLIC.

THE subjects of the following pages are chiefly compiled at the instigation of pressing solicitations by numerous individuals, no few of whom complain of the want of a convenient Text Book of Reference in which Mechanical and Commercial demands are judiciously combined. Others, with apparently equal reasons, for the sake of instruction, complain of the want of a compendium in which tuition and practical reference are discriminately arranged ; and generally, that for purposes of estimation, no properly portable work is yet in existence ; hence it is with a wish to diminish those wants in some degree that the present attempt has been made to supply the necessary information.

In regard to the selection, great care has been taken that the subjects be not only intimately interwoven, but also of such a nature as business transactions call most frequently into requisition.

The elementary or educational portion will be found exceedingly plain, simple, and aptly adapted ; also the practical rules much abbreviated through the application of decimal approximates, by which results are obtained sufficiently exact, and the means of calculation considerably facilitated.

That the production might be rendered still more worthy of public patronage, numerous diagrams, and several engravings, are annexed, which add much to its value in regard to practical utility; and it only remains to add the hope, that the Operative, the Man of Science, and an interested Public, may give due appreciation to the work, in proportion to its merits.

W. T.

The present edition has been much extended by the insertion of numerous Tables for the use of Operative Smiths, Millwrights, and Engineers, and by a further addition of Practical Observations on the Smelting of Metallic Ores.

May, 1855.

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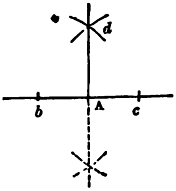
THE WORKSHOP COMPANION.

PRACTICAL GEOMETRY.

Geometry is the science which investigates and demonstrates the properties of lines on surfaces and solids: hence, **Practical Geometry** is the method of applying the rules of the science to practical purposes.

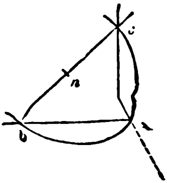
1. *From any given point, in a straight line, to erect a perpendicular; or, to make a line at right angles with a given line.*

On each side of the point A from which the line is to be made, take equal distances, as A *b*, A *c*; and from *b* and *c* as centres, with any distance greater than *b* A, or *c* A, describe arcs cutting each other at *d*; join A *d*, which will be the perpendicular required.



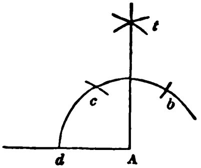
2. *When a perpendicular is to be made at or near the end of a given line.*

Take any point *n* above A *b*, and with centre *n* and distance *n* A, describe a circle, cutting the given line at *b*; through *b* and the centre *n*, draw the diameter *b n c*, and join *c* A, which will be the perpendicular required.



3. *To do the same otherwise.*

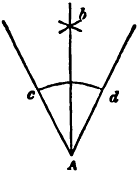
From the given point A, with any convenient radius, describe the arc *d c b*; with the same radius from *d*, cut the arc in *c*, and from *c*, cut the arc in *b*; also from *c* and *b* as centres, with the same or any other radius, describe arcs cutting each other in *t*; then will the line A *t* be the perpendicular required.



Note.—When the three sides of a triangle are in the proportion of 3, 4, and 5 equal parts respectively, two of the sides form a right angle; and observe that in each of the preceding problems, the perpendiculars may be continued below the given lines, if necessarily required.

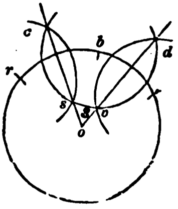
4. *To bisect any given angle.*

From the point A as a centre, with any radius less than the extent of the angle, describe an arc, as *c d*; and from *c* and *d* as centres, describe arcs cutting each other at *b*; then will the line A *b* bisect the angle as required.

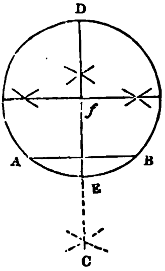


5. *To find the centre of a circle that shall cut any three given points, not in a direct line.*

From the middle point *b* as a centre, with any radius, as *b c*, *b d*, describe a portion of a circle, as *c s d*; and from *r* and *t* as centres, with an equal radius, cut the portion of the circle in *c*, *s* and *d*, *v*; draw lines through where *the arcs cut each* other, and the



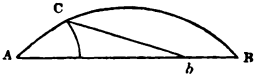
intersection of the lines at *o* is the centre of the circle required.



6. *To find the centre of a given circle.*

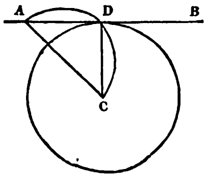
Bisect any chord in the circle, as A B, by a perpendicular C D; bisect also the diameter E D in *f*, and the intersection of the lines at *f* is the centre of the circle required.

7. *To find the length of any given arc of a circle.*



With the radius A C, equal to ¼th the length of the chord of the arc A B, and from A as a centre, cut the arc in C; also from B as a centre, with equal radius, cut the chord in *b*; draw the line C *b*, and twice the length of the line is the length of the arc nearly.

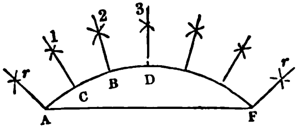
8. *Through any given point, to draw a tangent to a circle.*



Let the given point be at A: draw the line A C, on which describe the semicircle A D C; join A D, which, produced if necessary, is the tangent required.

9. To draw from, or to the circumference of a circle *lines tending towards the centre, when the centre is inaccessible.*

Divide the whole or any given portion of the circumference into the desired number of equal parts; then with any radius less than the distance of two divisions, describe arcs cutting each other, as A 1, B 1, C 2, D 2, &c.; draw the lines C 1, B 2, D 3, &c., which lead to the centre as required.

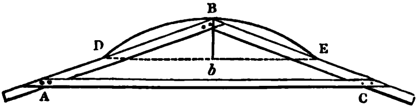


To draw the end lines,

As A *r*, F *r*, from C describe the arc *r*, and with the radius C 1, from A or F as centres, cut the former arcs at *r*, or *r*, and the lines A *r*, F *r*, will tend to the centre as required.

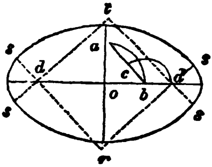
10. *On a given straight line, to describe an arc of a circle, the altitude being given.*

Let D E be the given straight line, B *b* the given altitude: join D B, B E, and of any suitable material



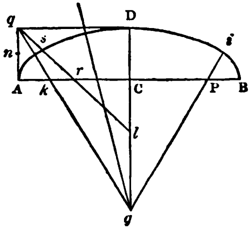
construct a triangle, as A B C, making each of the sides A B, B C, equal at least to the chord D E, and the angle contained by them equal to D B E; at each end of the chord D E, fix a pin, and at B a tracer, as a pencil; move the triangle along the pins as guides, and the tracer will describe the arc required.

11. *To describe an ellipse, having the two diameters given.*



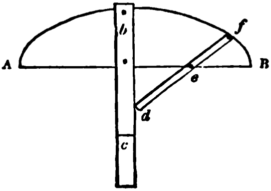
On the intersection of the two diameters as a centre, with a radius equal to the difference of the semi-diameters, describe the arc *a b*, and from *b* as a centre, with half the chord *b c a*, describe the arc *c d*; from *o*, as a centre, with the distance *o d*, cut the diameters in *d*, *r*, *d*, *t*; draw the lines *r s*, *r s*, *t s*, *t s*, then from *r* and *t* describe the arcs *s s*, *s s*; also from *d* and *d* describe the smaller arcs *s s*, *s s*, which will complete the ellipse as required.

12. *To describe an elliptic arch, the width and rise of span being given.*



Bisect with a line at right angles the chord or span A B, erect the perpendicular A *q*, and draw the line *q* D equal and parallel to A C; bisect A C and A *q* in *r* and *n*, make C *l* equal to C D, and draw the line *l r q*; draw also the line *n s* D; bisect *s* D with a line at right angles, and meeting the line C D produced in *g*; draw the line *g q*, make C P equal to C *k*, and draw the line *g* P *i*; then from *g* as a centre, with the radius *g* D, describe the arc *s* D *i*, and from *k* and P as centres, with the radius A *k*, describe the arcs A *s* and B *i*, which completes the arch as required. *Or*,

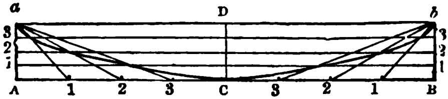
13. Bisect the chord A B, and fix at right angles any *straight guide*, as *b* C; prepare of any suitable



material a rod or staff, equal to half the chord's length, as *d e f*; from the end of the staff, equal to the height of the arch, fix a pin *e*, and at the extremity a tracer *f*; move the staff, keeping its end to the guide and the fixed pin to the chord, and the tracer will describe one-half the arch required.

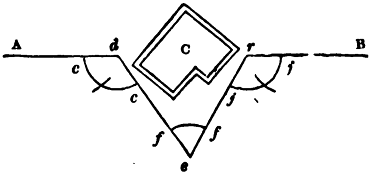
14. *To describe a parabola, the dimensions being given.*

Let A B equal the length, and C D the breadth of



the required parabola: divide C A, C B into any number of equal parts, also divide the perpendiculars A *a* and B *b* into the same number of equal parts; then from *a* and *b* draw lines meeting each division on the line A C B, and a curve line drawn through each intersection will form the parabola required.

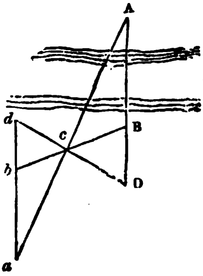
15. *To obtain by measurement the length of any direct line, though intercepted by some material object.*



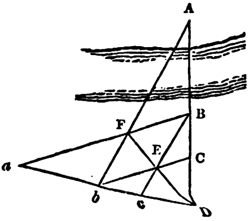
Suppose the distance between A and B is required, but the right line is intercepted by the object C. On the *point d*, with any convenient radius, describe the arc *c c*, make the arc twice the radius in length, through which draw the line *d c e*, and on *e* describe another arc equal in length to once the radius, as *e f f*; draw the line *e f r* equal to *e f d*; on *r* describe the arc *j j*, in length twice the radius; continue the line through *r*, *j*, which will be a right line, and *d e* or *e r*, will equal the distance between *d*, *r*, by which the distance between A and B is obtained as required.

16. *To ascertain the distance geometrically, of any inaccessible object on an equal plane.*

Let it be required to find the distance between A and B, A being inaccessible: produce the line in the direction of A B to any point, as D; draw the line D *d* at any angle to the line A B; bisect the line D *d* in *c*, through which draw the line B *b*, making *c b* equal to B *c*; join A *c*, and draw *d b a* meeting A *c*, produced in *a*. Then *b a*, equal to A B, is the distance required.



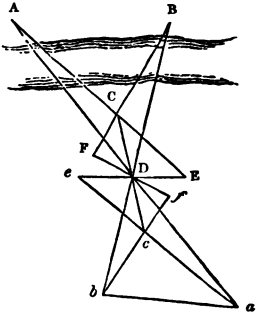
17. *Or otherwise,*



Produce A B to any point D, and bisect B D in C; through D draw D *a*, making any angle with D A, and take D *c*, D *b*, equal to D C and D B respectively; join B *c*, C *b*, and A *b*. Through E, the intersection of B *c*, C *b*, draw D E F meeting A *b* in

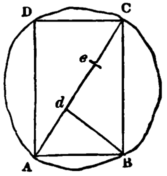
F; join B F, which being produced will meet D *a* in *a*. Then *a b* is equal to A B, the distance required.

18. *To measure the distance between two objects, both being inaccessible.*



From any point C draw any line C *c*, and bisect it in D; take any point E in the prolongation of A C, and draw the line E *e*, making D *e* equal to D E; in like manner take any point F in the prolongation of B C, and make D *f* equal to F D. Produce A D and *e c* till they meet in *a*, and also B D and *f c* till they meet in *b*; then *a b* is equal to A B, or the distance between the objects as required.

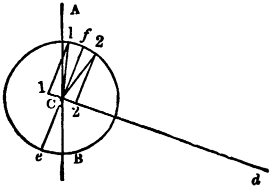
19. *A round piece of timber being given, out of which to cut a beam of strongest section.*



Divide into three equal parts any diameter in the circle, as A *d*, *e* C; from *d* or *e*, erect a perpendicular meeting the circumference of the circle, as *d* B; draw A B and B C, also A D equal to B C, and D C equal to A B, and the rectangle will be a section of the beam as required.

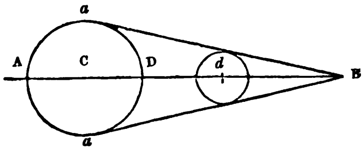
20. *To find the proper position for an eccentric, in relation to the crank in a steam engine, the angle*

of eccentric rod and travel of the valve being given.

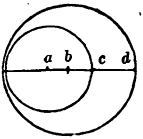


Draw the right line A B, as the situation of the crank at commencement of the stroke; draw also the line C *d*, as the proper given angle of eccentric rod with the crank; then from C as centre, describe a circle equal to the travel of the valve; draw the line *e f* at right angles to the line C *d*; draw also the lines 1 1, and 2 2, parallel to the line *e f*; and at a distance from *e f* on each side, equal to the lap and lead of the valve, draw the angular lines C 1, C 2, which are the angles of eccentric with the crank, for forward or backward motion, as may be required.

21. *The throw of an eccentric, and the travel of the valve in a steam engine, also the length of one lever for communicating motion to the valve, being given, to determine the proper length for the other.*



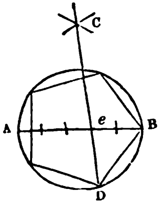
On any right line, as A B, describe a circle A D, equal to the throw of eccentric and travel of valve; then from C as a centre, with a radius equal to the length of lever given, cut the line A B, as at *d*, on which describe a circle, equal to the throw of eccentric or travel of valve, as may be required; draw the tangents B *a*, B *a*, cutting each other in the line A B, and *d* B is the length of the lever as required.



Note.—The throw of an eccentric is equal to the sum of twice the distance between the centres of formation and revolution, as *a b*, or to the degree of eccentricity it is made to describe, as *c d*. And

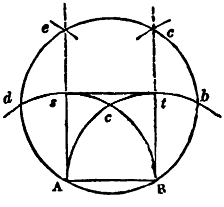
The travel of a valve is equal to the sum of the widths of the two steam openings, and the valve's excess of length more than just sufficient to cover the openings.

22. *To inscribe any regular polygon in a given circle.*



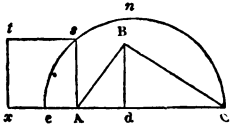
Divide any diameter, as A B, into so many equal parts as the polygon is required to have sides; from A and B as centres, with a radius equal to the diameter, describe arcs cutting each other in C; draw the line C D through *e*, the second point of division on the diameter, and the line D B is one side of the polygon required.

23. *To construct a square upon a given right line.*



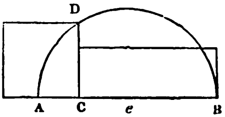
From A and B as centres, with the radius A B, describe the arcs A *c b*, B *c d*, and from *c* with an equal radius describe the circle or portion of a circle *e d* A B *b c*; from *b, d*, cut the circle at *e* and *c*; draw the lines A *e*, B *c*, also the line *s t*, which completes the square as required.

24. *To form a square equal in area to a given triangle.*



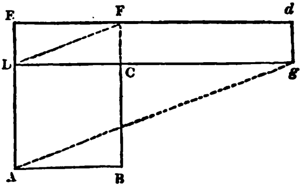
Let A B C be the given triangle: let fall the perpendicular B *d*, and make A *e* half the height *d* B; bisect *e* C, and describe the semicircle *e n* C; erect the perpendicular A *s*, or side of the square, then A *s t x* is the square of equal area as required.

25. *To form a square equal in area to a given rectangle.*



Let the line A B equal the length and breadth of the given rectangle: bisect the line in *e*, and describe the semicircle A D B; then from A with the breadth, or from B with the length of the rectangle, cut the line A B at C, and erect the perpendicular C D, meeting the curve at D, and C D is equal to a side of the square required.

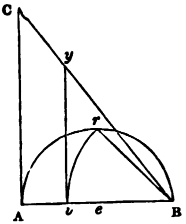
26. *To find the length for a rectangle whose area shall be equal to that of a given square, the breadth of the rectangle being also given.*



Let A B C D be the given square, and D E the given breadth of rectangle. Through E draw E F parallel to A B or D C; produce B C to F, and join D F. Through A draw A *g* parallel to D F, cutting D C produced in *g*, through which draw *g d* parallel to D E, meeting E F produced in *d*. E D *g d* is the rectangle required.

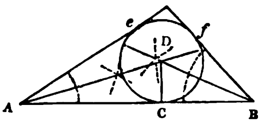
27. *To bisect any given triangle.*

Suppose A B C the given triangle: bisect one of its sides, as A B in *e*, from which describe the semicircle A *r* B; bisect the same in *r*, and from B with the distance B *r*, cut the diameter A B in *v*; draw the line *v y* parallel to A C, which will bisect the triangle as required.



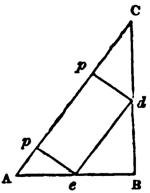
28. *To describe a circle of greatest diameter in a given triangle.*

Bisect the angles A and B, and draw the intersecting lines A D, B D, cutting each other in D; then from D as centre, with the distance D C, which is drawn perpendicular to A B, describe the circle, C *e f*, as required.



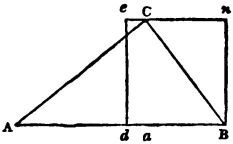
29. *To form a rectangle of greatest surface, in a given triangle.*

Let A B C be the given triangle: bisect any two of its sides, as A B, B, C, in *e* and *d;* draw the line *e d;* also at right angles with the line *e d*, draw the lines *e p*, *d p*, and *e p p d* is the rectangle required.

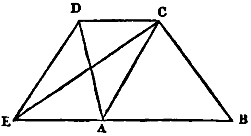


30. *To make a rectangle equal to a given triangle.*

Suppose A B C the given triangle: bisect A B in *d*, and erect the perpendicular *d e;* erect also the perpendicular B *n*; through C draw the line *e* C *n* parallel to A B, meeting the above in *e* and *n* respec*tively; then e d* B *n* is the rectangle as required.

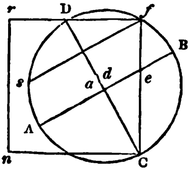


31. *To make a triangle equal to a given quadrilateral, as* A B C D.



Prolong the line B A, and draw the line A C; draw also the line D E parallel to A C, and cutting the line B A in E; then draw the line E C, and C E B is the triangle required.

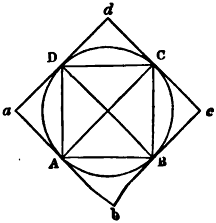
32. *To form a square nearly equal in area to a given circle.*



Let A C B D be the given circle: draw the diameters A B and C D at right angles to each other, bisect the radius *d* B in *e*, and draw the line C *e f*; draw also at right angles the lines C *n* and *f r*, making each equal to C *f*; join *n r*, and *n* C *f r* is the square as required.

Note.—The line *s f* is equal to one-fourth the circumference of the circle.

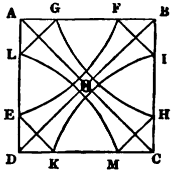
33. *To inscribe or describe a square within or without a given circle: also to form an octagon from a given square.*



1. Let A B C D be the given circle: draw the diameters A C, B D, at right angles to each other, and join A B, B C, C D, D A, which will complete the inscribed square: through the extremities of the same diameters *draw a b, c d,* parallel

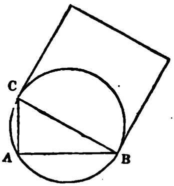
to B D, and *a d*, *b c*, parallel to A C, which will complete the square equal in breadth to the diameter of the circle.

2. Let A B C D be the given square. Draw the two diagonal lines A C and B D intersecting in O; then with a radius equal to A O, or half the diagonal, and with A as a centre, describe the arc E F, cutting the sides of the square in E and F; then from B as a centre, describe the arc G H, and in the same manner from C and D describe the arcs I K and L M. Draw the lines L G, F I, H M, and K E, which, with the parts G F, I H, M K, and E L, form the octagon required.



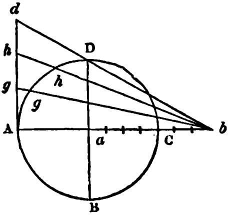
34. *To form a square equal to two given squares, or, a circle equal to two given circles.*

Let A B, A C, equal the sides of the given squares, or diameters of the given circles: make the angle at A a right angle, and draw the line C B, which is the side of a square equal to both the given squares; or bisect the line C B as a diameter, on which describe the circle C B A, which is equal to the two given circles as required.



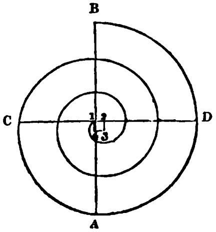
35. *To draw a right line equal to any given portion of the circumference of a circle.*

Let A B C D be a given circle, the whole circumference of which is required: draw at right angles the diameters A C, B D, divide the radius *a* C into four equal parts, and make C *b* equal to three of them; draw the tangent A *d* parallel to B D, draw the line *b* D *d*, then will A *d* equal one-fourth of the whole circumference; and if lines be drawn from *b*, through points in the circumference, meeting the line A *d*, as *g g*, *h h*, &c., the corresponding parts will be equal to each other.

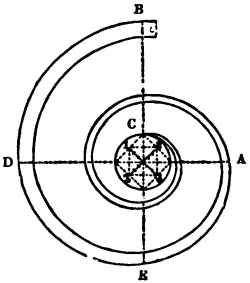


36. To draw a spiral with spaces of uniform distance.

Bisect the height of the spiral, as A B, and divide either half into the number of spaces or revolutions required; then again subdivide any one space into four equal parts, one of which add to half the height of the spiral, and through which draw the line C D at right angles to A B, thus forming the centre of the spiral, around which and equal to one of the subdivisions form a square, its sides being parallel with the lines A B and C D, the angles of which are the centres from whence to describe the various curves; as from 1, with the distance 1 B, describe the curve B D; from 2, with the distance 2 D, describe D A; from 3, with the distance 3 A, describe A C, &c., &c., and from the same centres the spiral may be continued to any extent required.

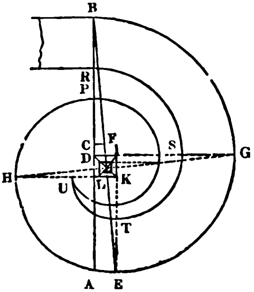


37. *To draw a volute for the capital of the Ionic column.*



Draw at right angles C A, C B, and on the centre C describe a circle equal to one-fourth of the height C B; form a square in the circle, the diagonals of which correspond with or cut the diameters A D, E B; bisect the square with lines crossing each other in the centre C, and parallel with the sides of the square; divide each into six equal parts, which are the centres from which the volute is to be described: thus, from 1, with the distance 1 B, describe the curve B D; from 2, with 2 D, describe D E; from 3, with 3 E, describe E A, &c., approaching the centre by degrees until the volute is completed as required.

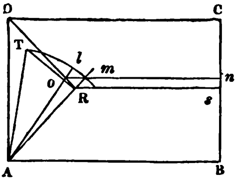
38. *To draw a scroll for the termination of a hand-rail, &c.*



Let A B equal the given breadth: draw A E perpendicular to A B, which divide into eleven equal parts, and A E equal to one of them; join B E, bisect A B in C and B E in F, make C D equal to C F, and draw D G perpendicular to A B; from F, with the radius F E, or F B, describe an arc cutting D G at G; draw G H perpendicular to B E, cutting *B E at O (or centre* of the scroll); draw the diagonals

D O K, I O L, perpendicular to D O K; draw I K parallel to B A, K L parallel to I D, &c., meeting the diagonals; from D as a centre, with the distance D B, describe the arc B G; from I as a centre, with the distance I G, describe G E; from K, with the distance K E, describe K H, &c., proceeding in the same manner until the outside of the scroll is completed; make B R equal to the breadth of the rail; then from D, with the distance D R, describe the arc R S; from I, and distance I S, describe S T; and from T, with K T, describe T U, which completes the scroll as required.

39. *To find the various angles and proper dimensions of materials whereby to construct any figure whose form is the frustum of a proper or inverted pyramid, as hipped roofs, mill hoppers, &c., &c.*



Let A B C D be the given dimensions of plan for a roof, the height R T also being given; draw the diagonal A R, meeting the top or ridge R *s* on plan; from R, at right angles with A R and equal to the required height, draw the line R T, then T A, equal the length of the struts or corners of the roof; from A, with the distance A T, describe an arc T *l*, continue the diagonal A R until it cuts the arc T *l*, through which, and parallel with the ridge R *s*, draw the line *m n*, which determines the required breadth for each side of the roof: from A, meeting the line *m n*, draw the line A *o*, or proper angle for the end of each board by which the roof might require to be covered; and the angle at T is what the boards require to be made in the direction of their thickness, when the corners or angles require to be mitred.

into any number of equal parts, as C, *e*, *f*, *g*, *h*, *i*, D, from which draw lines parallel to the line A B; divide the lines C F, D F, into equal divisions of half the required pitch or consecutive threads, as *t*, *r*, *v*, &c.; draw the lines *t t*, *r r*, *v v*, &c., parallel with the diameter C D, and subdivide any two connected divisions into the same number of equal parts contained in both semicircles, from which draw lines meeting the vertical lines; then by hand, or otherwise, and through the intersections, draw the waved lines, *m*, *n*, *p*, *q*, &c., and a thread of the screw is delineated as required.

Note.—The same process might be continued throughout the whole length of the screw, but it is much more convenient, when the proper curves are obtained, to form a suitable ruler: lay it in its proper situation upon each division, and draw the lines as required.

42. *To delineate a square-threaded screw, the pitch and diameter of screw being given.* (See Plate A, fig. 2.,

On the line A B representing the centre of the screw, describe the semicircles C D, *c d*, equal to the diameters at the tops and bottoms of the threads; divide each semi-circumference into four equal parts, draw lines from each and parallel to the line A B; draw also the lines C F, D F, which divide into the proper required pitch, as *a a*, *b b*, *c c*, &c.; divide any two connected pitches or divisions, as *a*, *b*, into four equal parts, from which draw lines parallel to the diameter C D, meeting the vertical lines *o*, *p*, *q*, and forming intersections through which the waved lines *s*, *n*, *i*, *s*, *n*, *i*, or tops of the threads, must be traced by hand or otherwise; draw also the lines *x*, *y*, forming intersections through which to trace the curve surface exhibited between and caused by the angular return of the thread; describe also the curves *k* and *b*, which terminates the returning thread, and completes the delineation as required.

Fig. 3, as to mode of construction, is exactly similar to that of fig. 2, but intended, by displacement of the cylinder, to delineate a continuous vein of the spiral in its proper form around the whole circumference: hence, being deemed by the preceding figure already sufficiently described, further elucidation must be considered unnecessary.

43. *To determine the proper forms for a pair of bevel wheels, the required angle of the shafts and diameters of the wheels being given.*

Draw at the given angles lines representing the shafts on which the wheels are to be fixed, as A B, A C; make the lines *a b*, *a c*, parallel with and at a distance from A B, A C, equal to the radius of each respective wheel at the greatest pitch circle; draw the line A *a* through the intersection at *d*; then from *a* at right angles with A B, A C, draw the lines *a e*, *a f*, making each in length equal to the wheel's diameter; draw the lines A *e*, A *f*, and from *a*, with the intended breadth of the wheels on the face, cut the line A *a* in *d*; draw the lines *d i*, *d g*, parallel to *a e*, *a f*, (hence the proper conical forms of the wheels and the pitch circles;) draw at right angles with A *a*, and through the intersection of the lines *a e*, *a f*, the line C B, also *the lines* B *e*, *c f*, *d k i*, *d l g*; from B and C, with

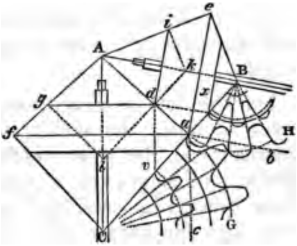
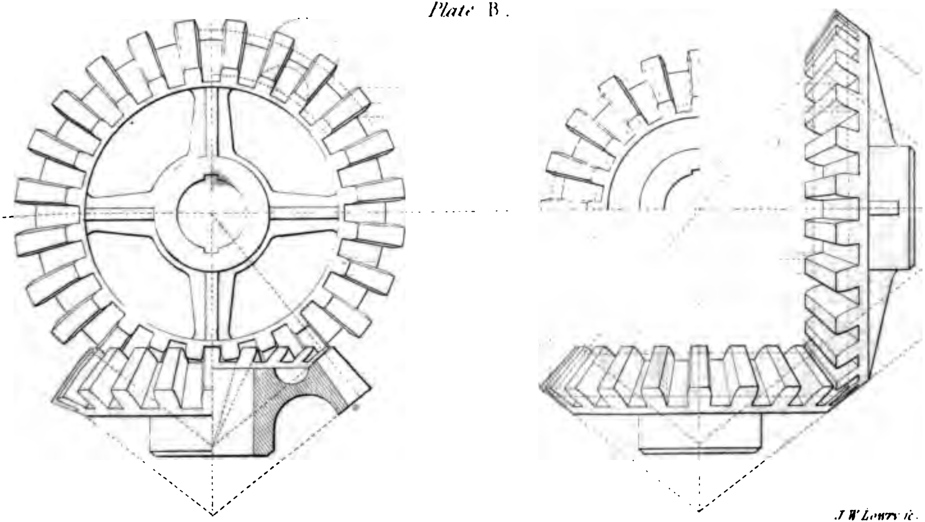


Plate B.



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the radius B a, C a, describe portions of circles, as a G, a H, on which describe the greatest dimensions of, and proper form of the teeth; then from d, and parallel with A B, A C, draw the lines a v, a x, cutting the line C B in v and x; from B and C, with the distances C v, B x, describe the portions of circles, which determines the dimensions of the teeth on the interior pitch circle, and completes the proper forms of the wheels as required.

Proportions for the construction of toothed wheels.

Length of the teeth = $\frac{5}{7}$ of the pitch.
Thickness " = $\frac{4}{9}$ do.
Breadth on face = $2\frac{1}{2}$ times the pitch.

$$\left.\begin{array}{l}\text{Edge of the rim}\\\text{Projecting rib inside do.}\\\text{Thickness of flat arms}\end{array}\right\}\text{each } \tfrac{4}{9} \text{ of the pitch.}$$

Breadth of arms at rim = 2 teeth and $\frac{1}{4}$ the pitch, increasing in breadth towards the centre of the wheel, in the proportion of $\frac{1}{2}$ an inch for every foot in length.

Thickness of the ribs or feathers on the arms = $\frac{1}{4}$ of the pitch.

Thickness of metal around the eye, or centre, = $\frac{7}{9}$ of the pitch.

Wheels and other circular bodies are very conveniently transferred from plan to that of a projected perspective by means of a peculiar appropriation of straight lines, commonly called orthographic projection, the principle of which will be readily understood by reference to the diagrams and illustrations given for the purpose in Plate C.

Fig. 1 is a circle divided into equal parts, and its form in projection is required, v n being supposed the line of *intersection*: parallel with the diameter of the circle *b f*, draw at right angles, and through the centre, the line *c e*; draw also the line or chord *f g*, cutting the line *v n* in *g*; then, with the distance *v g*, describe the quadrant *i r s*; bisect the arc in *r*, from which and parallel with *v n*, draw the line *r t*; draw also the lines *f t*, *g t*, which determines the breadth of the ellipsis or projected form of the circle, and which may be drawn as described (page 5, fig. 12): hence all the other lines being so distinctly described, by mere inspection of the diagrams, further explanation is unnecessary.

Fig. 2 is a projected representation of an undershot water-wheel, of which A is the plan, *v n* the line of intersection, and B the diameter and breadth, laid at a proper angle or inclination, as determined by the principles of the diagrams: the breadth of the ellipsis is found and formed as there described, and the lines in the illustration, or fig. 2, whereby to obtain the proper angles for projection, render sufficiently explicit the proper mode by which the representation is effected.

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Fig. 1

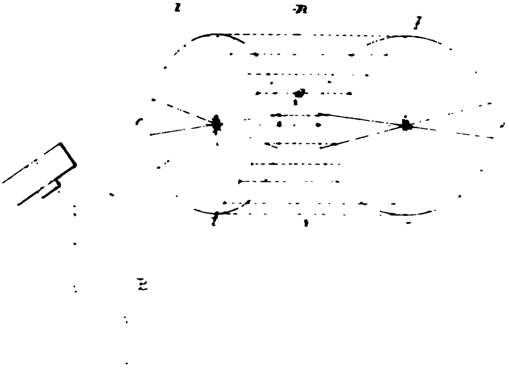
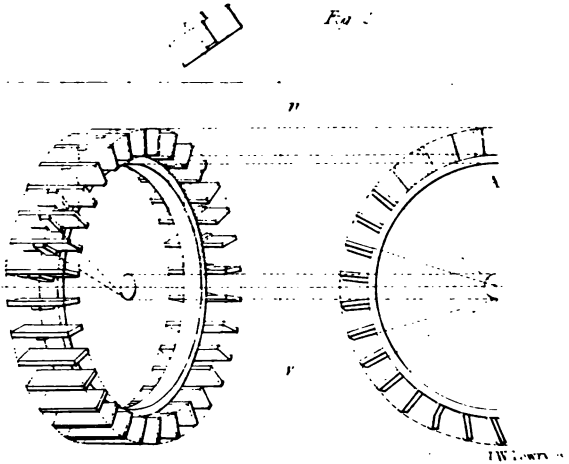


Fig. 2



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DECIMAL ARITHMETIC.

◆

Decimal Arithmetic is the most simple and explicit mode of performing practical calculations; on account of its doing away with the necessity of fractional parts in the fractional form, thereby reducing long and tedious operations to a few figures, arranged and worked in all respects according to the usual rules of common arithmetic.

Decimals simply signify tenths: thus, the decimal of a foot is the tenth part of a foot, the decimal of that tenth is the hundredth of a foot, the decimal of that hundredth is the thousandth of a foot, and so might the divisions be carried on and lessened to infinity; but in practice it is seldom necessary to take into account any degree of less measure than a one-hundredth part of the integer or whole number. And, as the entire system consists in supposing the whole number divided into tenths, hundredths, thousandths, &c., no peculiarity of notation is required, otherwise than placing a mark or dot, to distinguish between the whole and any part of the whole: thus 34·25 gallons signify 34 gallons 2 tenths and 5 hundredths of a gallon; 11·04 yards signify 11 yards and 4 hundredths of a yard; 16·008 shillings signify 16 shillings and 8 thousandth parts of a shilling: from which it must appear plain, that ciphers on the right hand of decimals are of no value whatever; but placed on the left hand, they diminish the decimal value in a tenfold proportion,—for ·6 signifies 6 tenths; ·06 signifies 6 hundredths; and ·006 signifies 6 thousandths, of the integer or whole number.

REDUCTION.

Reduc*tion means* the construing or changing of vulgar fractions to decimals of equal value; also finding the fractional value of any decimal given.

Rule 1. Add to the numerator of the fraction any number of ciphers at pleasure, divide the sum by the denominator, and the quotient is the decimal of equivalent value.

Rule 2. Multiply the given decimal by the various fractional denominations of the integer or whole number, cutting off from the right hand of each product for decimals a number of figures equal to the given number of decimals, and thus proceed until the lowest degree, or required value, is obtained.

Ex. 1. Required the decimal equivalent, or decimal of equal value, to $\frac{3}{12}$ of a foot.

$$\frac{3\cdot 00}{12} = \cdot 25, \text{ the decimal required.}$$

Ex. 2. Reduce the fraction $\frac{1}{8}$ of an inch to a decimal of equal value.

$$\frac{1\cdot 000}{8} = \cdot 125, \text{ the decimal required.}$$

Ex. 3. What is the decimal equivalent to $\frac{7}{8}$ of a gallon?

$$\frac{7\cdot 000}{8} = \cdot 875, \text{ the decimal equivalent.}$$

Ex. 4. Required the value of the decimal ·40625 of an inch.

$$\begin{array}{lr} & \cdot 40625 \\ \text{Multiply by } \frac{1}{8} & 8 \\ \hline & 3\cdot 25000 \\ +\frac{2}{16}=\frac{1}{8} & 2 \\ \hline & \cdot 50000 \\ +\frac{2}{32}=\frac{1}{16} & 2 \\ \hline & 1\cdot 00000 \end{array}$$

$\frac{3}{8}$ and $\frac{1}{32}$ of an inch, the value required.

Ex. 5. What is the value of ·625 of a cwt.?

$$\begin{array}{lrl} & \cdot625 & \\ \text{Multiply by 4 qrs.} & 4 & \\ \cline{2-2} & 2\cdot500 & \\ \times\ 28\ \text{lbs.} & 28 & \\ \cline{2-2} & 14\cdot000 & = \text{2 quarters and 14 lbs., the value required.} \\ \cline{2-2}\cline{2-2} \end{array}$$

Ex. 6. Ascertain the value of ·875 of an imperial gallon.

$$\begin{array}{lrl} & \cdot875 & \\ \text{Multiply by 4 quarts} & 4 & \\ \cline{2-2} & 3\cdot500 & \\ \times\ 2\ \text{pints} & 2 & \\ \cline{2-2} & 1\cdot000 & = \text{3 quarts and 1 pint, the value required.} \\ \cline{2-2}\cline{2-2} \end{array}$$

Ex. 7. What is the value of ·525 of a £. sterling?

$$\begin{array}{lrl} & \cdot525 & \\ \text{Multiply by 20 sh.} & 20 & \\ \cline{2-2} & 10\cdot500 & \\ \times\ 12\ \text{pence} & 12 & \\ \cline{2-2} & 6\cdot000 & = \text{10 shillings and 6 pence, the value required.} \\ \cline{2-2}\cline{2-2} \end{array}$$

Independent of the mark or dot which distinguishes between integers and decimals, the fundamental rules, viz., Addition, Subtraction, Multiplication, and Division, are in all respects the same as in Simple Arithmetic; and an example in each, illustrative of placing the separating point, will no doubt render the whole system sufficiently intelligible, even to the dullest capacity.

Ex. 1. Add into one sum the following intege and decimals.

16·625; 11·4; 20·7831; 12·125; 8·04; and 7·002.

```
 16·625
 11·4
 20·7831
 12·125
  8·04
  7·002
 -------
 75·9751 = the sum required.
```

Ex. 2. Subtract 119·80764 from 234·98276.

```
234·98276
119·80764
---------
115·17512 = the remainder required.
```

Ex. 3. Multiply 62·10372 by 16·732.

```
     62·10372
       16·732
     --------
     12420744
    18631116
   43472604
  37262232
  6210372
 ------------
 1039·11944304 = the product required.
```

Observe that the number of figures in the produ from the right hand, accounted as decimals, are equ to the number of decimals in the multiplier and mu *tiplicand* taken together.

Ex. 4. Divide 39·375 by 9·25.

```
9·25) 39·375 (4·256 = the quotient required.
      3700
      ————
       2375
       1850
       ————
        5250
        4625
        ————
         6250
         5550
         ————
          700
          ====
```

Observe that the number of decimals in the divisor and quotient together, must be equal to the number in the dividend.

Note.—The operation might be still continued, so as to reduce the quotient to a degree of greater exactitude, but in practice it is quite unnecessary, being even now reduced to a measure of greater nicety than is commonly required.

Definitions of Arithmetical signs employed in the following calculations, which ought to be particularly attended to.

=	sign of	equality, and	signifies	equal to, as 3 added 4 = 7.
+	„	addition	„	plus or more, as 5 + 3 = 8.
−	„	subtraction	„	minus or less, as 8 − 3 = 5.
×	„	multiplication	„	multiplied by, as 8 × 3 = 24.
÷	„	division	„	divided by, 24 ÷ 4 = 6 or $\frac{24}{4}$ = 6.
: :: :		proportion	„	that 2 is to 3 as 4 is to 6, &c.
√	„	square root	„	evolution, or the extrⁿ. of roots;
∛	„	cube root	„	thus, √64 = 8 and ∛64 = 4.
4^2	„	to be squared	„	involution, or the raising of powers;
4^3	„	to be cubed	„	thus, $4^2 = 16$, and $4^3 = 64$.

$\overline{3+5} \times 4 = 32$ that, 3 plus 5, or 8 multiplied by 4 = 32.

$\sqrt{5^2-3^2} = 4$ 5 squared, minus 3 squared, the square root of the remainder = 4.

$\sqrt[3]{\frac{20 \times 12}{30}} = 2$, 20 multiplied by 12, and divided by 30, the cube root of the quotient = 2.

BRITISH STANDARD MEASURES.

1. *Measures of length.*

12 inches .... = 1 foot.
3 feet.. = 1 yard.
5½ yards .... = 1 pole or rod.
40 poles...................................... = 1 furlong.
8 furlongs, 1760 yards, or 5280 feet... = 1 mile.

2. *Measures of surface, or square measure.*

144 square inches .... = 1 square foot.
9 square feet .... = 1 square yard.
30¼ square yards.......................... = 1 square pole.
40 square poles .... = 1 rood.
4 roods, or 4840 square yards .... = 1 acre.

3. *Measures of solidity, or cubic measure.*

1728 cubic inches .... = 1 cubic foot.
27 cubic feet .... = 1 cubic yard.

4. *Measures of capacity.*

LIQUIDS.

8·665 cubic inches .... = 1 gill.
4 gills .... = 1 pint
2 pints .... = 1 quart.
4 quarts, or 277¼ cubic inches .... = 1 gallon.

GRAIN, FRUITS, &c.

2 gallons .... = 1 peck.
4 pecks, or 2218·192 cubic inches...... = 1 bushel.
8 bushels .... = 1 quarter.
5 quarters.................................... = 1 load.

5. *Measures of weight.*

TROY.

24 grains .... = 1 pennyweight.
20 pennyweights .... = 1 ounce
12 ounces .... = 1 pound.

AVOIRDUPOIS.

27·34375 troy grains .... = 1 dram.
16 drams .... = 1 ounce.
16 ounces .... = 1 pound.
14 pounds.................................... = 1 stone.
2 stones .... = 1 quarter.
4 quarters, or 112 lbs .... = 1 cwt.
20 cwt. .... = 1 ton.

BRITISH SPECIAL MEASURES.

1. *Lineal measures for land.*

7·92 inches = 1 link.
100 links, or 22 yards = 1 chain.
80 chains = 1 mile.
69·121 miles = 1 geog. degree.

2. *Square measures for land.*

62·7264 square inches = 1 square link.
10,000 square links = 1 square chain.
10 square chains = 1 acre.

3. *Nautical measures.*

6082·66 feet = 1 nautical mile.
3 miles = 1 league.
20 leagues = 1 degree.
360 degrees = the earth's circumference.

Miscellaneous special measures.

6 lineal feet = 1 fathom.
100 square feet = 1 square of flooring.
272 sq. feet, at 14 in. in thickness = 1 rod of brick-work.
600 square feet of inch boards... = 1 load.
40 cubic feet of round timber }
50 cubic feet of hewn timber } = 1 ton or load.
40 cubic feet = 1 ton of shipping.
120 deals = 1 hundred.
120 nails = 1 hundred.
1200 do. = 1 thousand.
500 bricks = 1 load.
32 bushels of lime = 1 do.
36 do. sand = 1 do.
19½ cwt. = 1 fother of lead.
108 cubic feet = 1 stack of wood.

42 gallons = 1 tierce
63 do. = 1 hogshead
84 do. = 1 puncheon
126 do. = 1 pipe
252 do. = 1 tun
} old wine measure.

36 do. = 1 barrel
54 do. = 1 hogshead
72 do. = 1 puncheon
108 do. = 1 butt
} old ale measure.

DECIMAL APPROXIMATIONS FOR FACILITATING CALCULATIONS IN MENSURATION.

Lineal feet	multiplied by	·00019	=	miles.
„ yards	„	·000568	=	„
Square inches	„	·007	=	square feet.
„ yards	„	·0002067	=	acres.
Circular inches	„	·00546	=	square feet.
Cylindrical inches	„	·0004546	=	cubic feet.
„ feet	„	·02909	=	cubic yards.
Cubic inches	„	·00058	=	cubic feet.
„ feet	„	·03704	=	cubic yards.
„ „	„	6·232	=	imperial gallons.
„ inches	„	·003607	=	„ „
Cylindrical feet	„	4·895	=	„ „
„ inches	„	·002832	=	„ „
Cubic inches	„	·263	=	lbs. av^{s}. of cast iron.
„ „	„	·281	=	„ wrought do.
„ „	„	·283	=	„ steel.
„ „	„	·3225	=	„ copper
„ „	„	·3037	=	„ brass.
„ „	„	·26	=	„ zinc.
„ „	„	·4103	=	„ lead.
„ „	„	·2636	=	„ tin.
„ „	„	·4908	=	„ mercury.
Cylindrical inches	„	·2065	=	„ cast iron.
„	„	·2168	=	„ wrought iron.
„	„	·2223	=	„ steel.
	„	·2533	=	„ copper.
„	„	·2385	=	„ brass.
„	„	·2042	=	„ zinc.
„	„	·3223	=	„ lead.
„	„	·207	=	„ tin.
„	„	·3854	=	„ mercury.
Avoirdupois lbs.	„	·009	=	cwts.
„	„	·00045	=	tons.

DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch, the integer or whole number.

·96875	are equal to	$\frac{7}{8}$ & $\frac{3}{32}$	·625	are equal to	$\frac{5}{8}$	·28125	are equal to	$\frac{1}{4}$ & $\frac{1}{32}$
·9375		$\frac{7}{8}$ & $\frac{1}{16}$	·59375		$\frac{1}{2}$ & $\frac{3}{32}$	·25		$\frac{1}{4}$
·90625		$\frac{7}{8}$ & $\frac{1}{32}$	·5625		$\frac{1}{2}$ & $\frac{1}{16}$	·21875		$\frac{1}{8}$ & $\frac{3}{32}$
·875		$\frac{7}{8}$	·53125		$\frac{1}{2}$ & $\frac{1}{32}$	·1875		$\frac{1}{8}$ & $\frac{1}{16}$
·84375		$\frac{3}{4}$ & $\frac{3}{32}$	·5		$\frac{1}{2}$	·15625		$\frac{1}{8}$ & $\frac{1}{32}$
·8125		$\frac{3}{4}$ & $\frac{1}{16}$	·46875		$\frac{3}{8}$ & $\frac{3}{32}$	·125		$\frac{1}{8}$
·78125		$\frac{3}{4}$ & $\frac{1}{32}$	·4375		$\frac{3}{8}$ & $\frac{1}{16}$	·09375		$\frac{3}{32}$
·75		$\frac{3}{4}$	·40625		$\frac{3}{8}$ & $\frac{1}{32}$	·0625		$\frac{1}{16}$
·71875		$\frac{5}{8}$ & $\frac{3}{32}$	·375		$\frac{3}{8}$	·03125		$\frac{1}{32}$
·6875		$\frac{5}{8}$ & $\frac{1}{16}$	·34375		$\frac{1}{4}$ & $\frac{3}{32}$			
·65625		$\frac{5}{8}$ & $\frac{1}{32}$	·3125		$\frac{1}{4}$ & $\frac{1}{16}$			

One foot, or 12 inches, the integer.

·9166	are equal to	11inches.	·4166	are equal to	5 in.	·0625	are equal to	$\frac{3}{4}$ of in.
·6338		10 "	·3333		4 "	·05208		$\frac{5}{8}$ "
·75		9 "	·25		3 "	·04166		$\frac{1}{2}$ "
·6666		8 "	·1666		2 "	·03125		$\frac{3}{8}$ "
·5833		7 "	·0833		1 "	·02083		$\frac{1}{4}$ "
·5		6 "	·07291		$\frac{7}{8}$ "	·01041		$\frac{1}{8}$ "

One yard, or 36 inches, the integer.

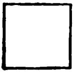
·9722	are equal to	35inches.	·6389	are equal to	23inches.	·3055	are equal to	11inches.
·9444		34 "	·6111		22 "	·2778		10 "
·9167		33 "	·5833		21 "	·25		9 "
·8889		32 "	·5556		20 "	·2222		8 "
·8611		31 "	·5278		19 "	·1944		7 "
·8333		30 "	·5		18 "	·1667		6 "
·8056		29 "	·4722		17 "	·1389		5 "
·7778		28 "	·4444		16 "	·1111		4 "
·75		27 "	·4167		15 "	·0833		3 "
·7222		26 "	·3889		14 "	·0555		2 "
·6944		25 "	·3611		13 "	·0278		1 "
·6667		24 "	·3333		12 "			

MENSURATION.

Mensuration is that branch of Mathematics which is employed in ascertaining the extension, solidities, and capacities of bodies, capable of being measured.

1. MENSURATION OF SURFACE.

To measure or ascertain the quantity of surface in any right-lined figure whose opposite sides are parallel to each other, as a

Square,


Rectangle,

Rhomboid,

&c.

Rule.—Multiply the length by the breadth; the product is the area or superficial contents.

Application of the rule to practical purposes.

1. The side of a square piece of board is $8\frac{3}{16}$ inches in length; required the area or superficies.

Decimal equivalent to the fraction $\frac{3}{16}$=·1875 (see page 31); and 8·1875 × 8·1875=67·03515625 square inches, the area.

2. The length of the fire-grate under the boiler of a steam engine is 4 feet 7 inches, and its width 3 feet 6 inches: required the area of the fire-grate.

7 in.=·5833 and 6 in.=·5 (see Table of Equivalents, p. 31): *hence 4·5833 × 3·5*=16·04155 square feet, the area.

3. Required the number of square yards in a floor whose length is $13\frac{1}{2}$, and breadth $9\frac{3}{4}$ feet.

$13{\cdot}5 \times 9{\cdot}75 = 131{\cdot}625 \div 9 = 14{\cdot}625$ square yards.

Note 1.—The above rule is rendered equally applicable to figures whose sides are not parallel to each other, by taking the mean breadth as that by which the contents are to be estimated.

2. The square root of any given sum equals the side of a square of equal area.

3. Any square whose side is equal to the diagonal of another square, contains double the area of that square.

4. Any sum or area (of which to form a rectangle) divided by the breadth, the quotient equals the length; or divided by the length, the quotient equals the breadth of the rectangle required.

TRIANGLES.

Any two sides of a right-angled triangle being given, to find the third side.

Rule 1.—Add together the squares of the base and perpendicular, and the square root of the sum is the hypotenuse or longest side.

Rule 2.—Add together the hypotenuse and any one side, multiply the sum by their difference, and the square root of the product equals the other side.

Application to practical purposes.

1. Wanting to prop a building with raking shores, the top ends of which to be 25 feet from the ground, and the bottom ends, 16 feet from the base of the building; what must be their length, independent of any extra length allowed below the surface of the ground?

$\overline{25^2+16^2} = \sqrt{881} = 29{\cdot}6816$ feet, or $\cdot 6816 \times 12 = 8$ inches; consequently, 29 feet 8 inches nearly.

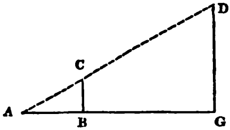
2. From the top of a wall 18 feet in height, a line was stretched across a canal for the purpose of ascer-

taining its breadth; the length of the line, when measured, was found to be 40 feet; required the breadth from the opposite embankment to the base of the wall.

$40-18=22$, and $\overline{40+18}\times 22=\sqrt{1276}=35\cdot72$, or 35 feet 9 inches nearly, the width of the canal.

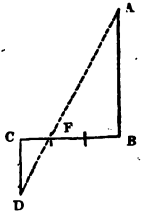
Triangles similar to each other are proportional to each other; hence their utility in ascertaining the heights and distances of inaccessible objects.

Thus, suppose the height of an inaccessible object D is required, I find by means of two staffs or otherwise, the height of the perpendicular B C and the length of the base line A B; also the distance from A to the base of the object G D;



then A B : B C : : A G : G D. And suppose A B=6 feet, B C=2 feet, and A G=150;
6 : 2 : : 150 : 50 feet, the height of D from G.

Again, suppose the inaccessible distance A be required, make the line B A, B C, at right angles, and B C of three or four equal parts of any convenient distance, through one of which and in a line with the object A, determine the triangle C D F, then the proportion will be as

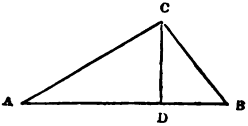


C F : C D : : B F : B A. Let C F=10 yards, C D=53, and B F=30, 10 : 53 : : 30 : 159 yards, the distance from B.

To find the area of a triangle when the base and perpendicular are given.

Rule.—Multiply the base by the perpendicular *height, and half* the product is the area.

1. The base of the triangle A D B is $11\frac{3}{32}$ inches in length, and the height D C, $3\frac{3}{8}$ inches; required the area.



$\frac{3}{32}=\cdot09375$ and $\frac{3}{8}=\cdot375$ (see page 31):

hence $\frac{11\cdot09375\times3\cdot375}{2}=18\cdot72075$ square inches, the area.

2. The base of a triangle is 53 feet 3 inches, and the perpendicular 7 feet 9 inches; required the area or superficies.

$$\frac{53\cdot25\times7\cdot75}{2}=206\cdot34375 \text{ square feet, the area.}$$

When only the three sides of a triangle can be given, to find the area.

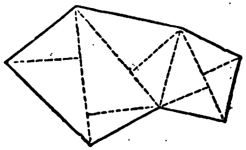
Rule.—From half the sum of the three sides, subtract each side severally; multiply the half sum and the three remainders together, and the square root of the product is equal to the area required.

Required the area of a triangle whose three sides are respectively 50, 40, and 30 feet.

$$\frac{50+40+30}{2}=60, \text{ or half the sum of the three sides.}$$

$60-30=30$, first difference,
$60-40=20$, second difference,
$60-50=10$, third difference;
then $30\times20\times10\times60=\sqrt{360000}=600$, the area required.

Triangles are employed to great advantage in determining the area of any rectilineal figure, as the annexed, and by which the measurement is rendered comparatively simple.



POLYGONS.

Polygons being composed of triangles, may of course be similarly measured: hence in regular polygons, multiply the length of a side by the perpendicular height to the centre, and by the number of sides, and half the product is the area.

Table relative to the Construction and Estimation of Polygons.

Name.	No. of sides.	Angle at centre.	Angle at circum.	Perpen. side being 1.	Length of side, radius being 1.	Radius of circle, side being 1.	Radius of circle, per. being 1.	Area, side being 1.
Triangle .	3	120°	60°	0·2886	1·73	·579	2	0·4330
Square . . .	4	90	90	0·5	1·412	·705	1·41	1
Pentagon .	5	72	108	0·6882	1·174	·852	1·238	1·7204
Hexagon .	6	60	120	0·8660	1	1	1·156	2·5980
Heptagon .	7	$51\frac{3}{7}$	$128\frac{4}{7}$	1·0382	·867	1·16	1·11	3·6339
Octagon .	8	45	135	1·2071	·765	1·307	1·08	4·8284
Nonagon .	9	40	140	1·3737	·681	1·47	1·062	6·1818
Decagon .	10	36	144	1·5388	·616	1·625	1·05	7·6942
Undecagon	11	$32\frac{8}{11}$	$147\frac{8}{11}$	1·7028	·561	1·777	1·04	9·3656
Dodecagon	12	30	150	1·8660	·516	1·94	1·037	11·1961

Application of the Table.

1. The radius of a circle being $6\frac{1}{2}$ feet, required the side of the greatest heptagon that may be inscribed therein.

$\cdot 867 \times 6\cdot 5 = 5\cdot 6355$, or 5 feet $7\frac{1}{2}$ inches nearly.

2. Each side of a pentagon is required to be 9 feet; required the radius of circumscribing circle.

$\cdot 852 \times 9 = 7\cdot 668$, or 7 feet 8 inches.

3. A perpendicular from the centre to either side of an octagon is required to be 12 feet; what must be the radius of circumscribing circle?

$1\cdot 08 \times 12 = 12\cdot 96$, or 12 feet $11\frac{1}{2}$ inches.

4. Each side of a hexagon is $4\frac{1}{2}$ yards; required its superficial contents.

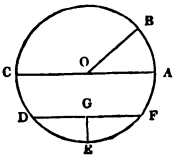
$4\frac{1}{2}^2 \times 2\cdot 598 = 52\cdot 6095$ square yards.

THE CIRCLE AND ITS SECTIONS.

Observations and Definitions.

1. The circle contains a greater area than any other plane figure bounded by the same perimeter or outline.

2. The areas of circles are to each other as the squares of their diameters; any circle twice the diameter of another contains four times the area of the other.



3. The radius of a circle is a straight line drawn from the centre to the circumference, as O B.

4. The diameter of a circle is a straight line drawn through the centre, and terminated both ways at the circumference, as C O A.

5. A chord is a straight line joining any two points of the circumference, as D F.

6. The versed sine is a straight line joining the chord and circumference, as E G.

7. An arc is any part of the circumference, as C D E.

8. A semicircle is half the circumference cut off by a diameter, as C E A.

9. A segment is any portion of a circle cut off by a chord, as D E F.

10. A sector is a part of a circle cut off by two radii, as A O B.

General rules in relation to the circle.

1. Multiply the diameter by 3·1416, the product is the circumference.

2. Multiply the circumference by ·31831, the product is the diameter.

3. Multiply the square of the diameter by ·7854, the product is the area.

4. Multiply the square root of the area by 1·12837, the product is the diameter.

5. Multiply the diameter by ·8862, the product is the side of a square of equal area.

6. Multiply the side of a square by 1·128, the product is the diameter of a circle of equal area.

Application of the rules as to purposes of practice.

1. The diameter of a circle being $7\frac{3}{16}$ inches, required its circumference.

7·1875 × 3·1416=22·58025 inches, the circumference.

Or, the diameter being $30\frac{1}{2}$ feet, required the circumference.

3·1416 × 30·5=95·8188 feet, the circumference.

2. *A straight* line, or the circumference of a circle,

being 274·89 inches, required the circle's diameter corresponding thereto.

$274{\cdot}89 \times {\cdot}31831 = 87{\cdot}5$ inches diameter.

Or, what is the diameter of a circle when the circumference is 39 feet?

${\cdot}31831 \times 39 = 12{\cdot}41409$ feet, and ${\cdot}41409 \times 12 = 4{\cdot}96908$ inches, or 12 feet 5 inches, very nearly the diameter.

3. The diameter of a circle is 3¾ inches; what is its area in square inches?

$3{\cdot}75^2 = 14{\cdot}0625 \times {\cdot}7854 = 11{\cdot}044$, &c. inches area.

Or, suppose the diameter of a circle 25 feet 6 inches, required the area.

$25{\cdot}5^2 = 650{\cdot}25 \times {\cdot}7854 = 510{\cdot}706$, &c. feet, the area.

4. What must the diameter of a circle be, to contain an area equal to 706·86 square inches?

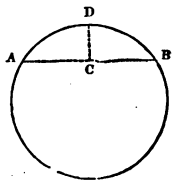
$\sqrt{706{\cdot}86} = 26{\cdot}586 \times 1{\cdot}12837 = 29{\cdot}998$ or 30 inches, the diameter required.

5. The diameter of a circle is 14¼ inches; what must I make each side of a square, to be equal in area to the given circle?

$14{\cdot}25 \times {\cdot}8862 = 12{\cdot}62835$ inches, length of side required.

Any chord and versed sine of a circle being given to find the diameter.

Rule.—Divide the sum of the squares of the chord and versed sine by the versed sine; the quotient is the diameter of corresponding circle.



1. The chord of a circle A B equal 6½ feet, and the versed sine C D equal 2 feet; required the circle's diameter.

$\overline{6{\cdot}5^2+2^2} = 46{\cdot}25 \div 2 = 23{\cdot}125$ feet, the diameter.

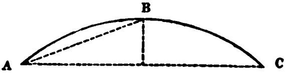
2. In a curve of a railway, I stretched a line 72 feet in length, and the distance from the line to the curve I found to be 1¼ ft.; required the radius of the curve.

$\overline{72^3+1{\cdot}25^2}=5185{\cdot}5625$, and $\frac{5185{\cdot}5625}{1{\cdot}25\times 2}=2074{\cdot}225$ ft. the radius.

To find the length of any given arc of a circle.

Rule.—From eight times the chord of half the arc, subtract the chord of the whole arc, and one-third of the remainder is equal the length of the arc.

Required the length of the arc A B C, the chord A B of half the arc being 4 feet 3 inches, and chord A C of the whole arc 8 feet 4 inches.

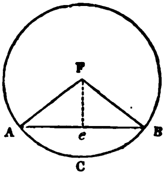


$4{\cdot}25\times 8=34$, and $34-8{\cdot}333=\frac{25{\cdot}667}{3}=8{\cdot}555$ feet, the length of the arc.

To find the area of the sector of a circle.

Rule.—Multiply the length of the arc by its radius, and half the product is the area.

The length of the arc A C B equal 9½ feet, and the radii F A, F B, equal each 7 feet; required the area.



$9{\cdot}5\times 7=65{\cdot}5\div 2=32{\cdot}75$, the area.

Note.—The most simple means whereby to find the area of the segment of a circle, is, to first find the area of a sector whose arc is equal to that of the given segment; and if it be less than a semicircle, subtract the area of the triangle formed by the chord of the segment and radii of its extremities; but if more than a semicircle, add the area of the triangle to the area of the sector, and the remainder or sum *is the area of the segment.*

Thus, suppose the area of the segment A C B *e* is required, and that the length of the arc A C B equal 9¾ feet, F A and F B each equal 7 feet, and the chord A B equal 8 feet 4 inches, also the perpendicular *e* F equal 3¾ feet.

$$\frac{9{\cdot}75 \times 7}{2} = 34{\cdot}125 \text{ feet, the area of the sector.}$$

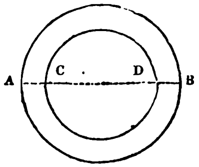
$$\frac{8{\cdot}333 \times 3{\cdot}75}{2} = 15{\cdot}624 \text{ feet, area of the triangle.}$$

And 34·125—15·624=18·501 feet, the area of the segment.

To find the area of the space contained between two concentric circles.

Rule.—Multiply the sum of the inside and outside diameters by their difference, and by ·7854; the product is the area.

1. Suppose the external circle A B equal 32 inches, and internal circle C D equal 28 inches; required the area of the space contained between them.



$\overline{32+28}=60$, and $32-28=4$; hence $60 \times 4 \times {\cdot}7854=188{\cdot}496$ in. the area.

2. The exterior diameter of the fly-wheel of a steam engine is 20 feet, and the interior diameter 18½ feet; required the area of the surface or rim of the wheel.

$\overline{20+18{\cdot}5}=38{\cdot}5$, and $20-18{\cdot}5=1{\cdot}5$; hence $38{\cdot}5 \times 1{\cdot}5 \times {\cdot}7854$ $=45{\cdot}35$, &c. feet, the area.

To find the area of an ellipse or oval.

Rule.—Multiply the longest diameter by the shortest, and the product by ·7854; the result is the area.

An oval is 25 inches by 16·5; what are its superficial contents?

$25 \times 16{\cdot}5 = 412{\cdot}5 \times {\cdot}7854 = 323{\cdot}9775$ inches, the area.

Note.—Multiply half the sum of the two diameters by 3·1416, and the product is the circumference of the oval or ellipse.

To find the area of a parabola, or its segment.

Rule.—Multiply the base by the perpendicular height, and two-thirds of the product is the area.

What is the area of a parabola whose base is 20 feet and height 12?

$$20 \times 12 = \frac{240 \times 2}{3} = 160 \text{ feet, the area.}$$

Note.—Although the whole of the preceding practical applications or examples are given in measures of feet or inches, these being considered as the most generally familiar, yet the rules are equally applicable to any other unit of measurement whatever, as yards, chains, acres, &c. &c. &c.

2. MENSURATION OF THE SUPERFICIES, SOLIDITIES, AND CAPACITIES OF BODIES.

To find the solidity or capacity of any figure in the cubical form.

Rule.—Multiply the length of any one side by its breadth and by the depth or distance to its opposite side; the product is the solidity or capacity, in equal terms of measurement.

Application of the rule to practical purposes.

1. Required the number of cubic inches in a piece of timber $23\frac{1}{2}$ inches long, $7\frac{3}{4}$ inches broad, and $3\frac{5}{8}$ inches in thickness.

$$23{\cdot}5 \times 7{\cdot}75 \times 3{\cdot}625 = 660{\cdot}203 \text{ cubic inches.}$$

2. A rectangular cistern is in length $8\frac{1}{2}$ feet, in *breadth* $5\frac{1}{4}$ feet, and in depth 4 feet; required its

capacity in cubic feet, also its capacity in British imperial gallons.

$8{\cdot}5 \times 5{\cdot}25 \times 4 = 178{\cdot}5$ cubic feet, and $178{\cdot}5 \times 6{\cdot}232$ (see Table of Decimal Approximations, p. 30) $= 1112{\cdot}412$ gallons.

3. A rectangular cistern capable of containing 520 imperial gallons is to be $7\frac{1}{4}$ feet in length, and $4\frac{1}{2}$ feet in width; it is required to ascertain the necessary depth.

$7{\cdot}25 \times 4{\cdot}5 \times 6{\cdot}232 = 203{\cdot}318$, and $\frac{520{\cdot}000}{203{\cdot}318} = 2{\cdot}557$ feet, or 2 feet $6\frac{3}{4}$ inches nearly.

4. A rectangular piece of cast iron, 20 inches long and 6 inches broad, is to be formed of sufficient dimensions to weigh 150 lbs.; what will be the depth required?

$20 \times 6 \times {\cdot}263$ (see Table of Decimal Approximations, Cast Iron, p. 30) $= 31{\cdot}96$, and $\frac{150}{31{\cdot}96} = 4{\cdot}69$ in., or 4 and $\frac{11}{16}$ in., the thickness required.

To find the convex surface, and solidity or capacity of a cylinder.

Rule. 1.—Multiply the circumference of the cylinder by its length or height; the product is the convex surface.

Rule 2.—Multiply the area of the diameter by the length or height; and the product is the cylinder's solidity or capacity, as may be required.

Application of the rules.

1. The circumference of a cylinder is $37\frac{1}{2}$ inches, and its length $54\frac{3}{4}$ inches; required the convex surface in square feet.

$54{\cdot}75 \times 37{\cdot}5 \times {\cdot}007$ (see Table of Approximations) $= 14{\cdot}371$ square feet.

2. A cylindrical piece of timber is 9 inches dia-

meter, and 3 feet 4 inches in length; required its solidity in cubic inches, and also in cubic feet.

3 feet 4 inches=40 inches, and $9^2 \times \cdot 7854 \times 40 = 2544\cdot 696$ cubic inches; then $2544\cdot 696 \times \cdot 00058 = 1\cdot 4759$ cubic feet.

3. Suppose a well to be 4 feet 9 inches diameter, and 16½ feet from the bottom to the surface of the water; how many imperial gallons are therein contained?

$$4\cdot 75^2 \times 16\cdot 5 \times 4\cdot 895 = 1822\cdot 162 \text{ gallons.}$$

4. Again, suppose the well's diameter the same, and its entire depth 35 feet; required the quantity in cubic yards of material excavated in its formation.

$$4\cdot 75^2 \times 35 \times \cdot 02909 = 22\cdot 973 \text{ cubic yards.}$$

5. I have a cylindrical cistern capable of holding 7068 gallons, and its depth is 10 feet; now I want to replace it with one of an equal depth, but capable of holding 12,500 gallons; what must be its diameter?

$4\cdot 895 \times 10 = 48\cdot 95$, and $\frac{12500}{48\cdot 95} = \sqrt{255\cdot 3} = 15\cdot 9687$ feet, or 15 feet $11\frac{5}{8}$ inches.

6. A cylindrical piece of lead is required 7½ inches diameter, and 168lbs. in weight; what must be its length in inches?

$$7\cdot 5^2 \times \cdot 3223 = 18, \text{ and } \frac{168}{18} = 9\cdot 3 \text{ inches.}$$

To find the length of a cylindrical helix, or spiral, wound round a cylinder.

Rule.—Multiply the circumference of the base by the number of revolutions of the spiral, and to the square of the product add the square of the height; the square root of the sum is the length of the spiral.

Application of the rule.

1. Required the length of the thread or screw twisting round a cylinder 22 inches in circumference $3\frac{1}{2}$ times, and extending along the axis 16 inches.

$22 \times 3{\cdot}5 = 77^2 = 5929$, and $16^2 = 256$; then $\sqrt{5929 + 256} = 78{\cdot}64$ inches.

2. The well of a winding staircase is 5 feet diameter, and height to the top landing 25 feet, the hand-rail is to make $2\frac{1}{2}$ revolutions; required its length.

5 feet diameter $= 15{\cdot}7$ feet circumference.
$15{\cdot}7 \times 2{\cdot}5 = 39{\cdot}25^2 = 1540{\cdot}5625$, and $25^2 = 625$; then
$\sqrt{1540 + 625} = 46{\cdot}5$ feet, the length required.

To find the convex surface, solidity, or capacity of a cone or pyramid.

Rule 1.—Multiply the circumference of the base by the slant height, and half the product is the slant surface.

Rule 2.—Multiply the area of the base by the perpendicular height, and one-third of the product is the solidity or capacity, as may be required.

Application of the rules.

1. Required the area in square inches of the slant surface of a cone whose slant height equals $18\frac{3}{4}$ inches, and diameter at the base $6\frac{1}{4}$ inches.

$6{\cdot}25 \times {\cdot}3{\cdot}1416 = 19{\cdot}635$, circumference of the base; and
$\frac{19{\cdot}635 \times 18{\cdot}75}{2} = 184{\cdot}078125$ square inches.

2. Required the quantity of lead, in square feet, sufficient to cover the slant surface of a hexagonal pyramid whose slant height is 42 feet, and the breadth of each side at the base 4 feet 9 inches.

$\frac{4{\cdot}75 \times 42 \times 6 \text{ sides}}{2} = 598{\cdot}5$ square feet.

3. What is the solidity of a cone in cubic inches, the diameter at the base being 15 inches, and perpendicular height $32\frac{1}{2}$ inches?

$$\frac{15^2 \times {\cdot}7854 \times 32{\cdot}5}{3} = 1914{\cdot}4125 \text{ cubic inches.}$$

4. In a square solid pyramid of stone 67 feet in height, and $16\frac{1}{2}$ feet at the base, how many cubic feet?

$$\frac{16{\cdot}5 \times 16{\cdot}5 \times 67}{3} = 6080{\cdot}25 \text{ cubic feet.}$$

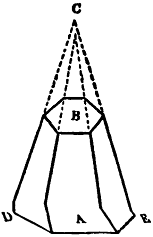
To find the solidity or capacity of any frustum of a cone or pyramid.

Rule.—If the base be a circle, add into one sum the two diameters, or, if a regular polygon, the breadth of one side at the top and at the base; then from the square of the sum subtract the product of these diameters or breadths; multiply the remainder by ·7854, if a circle, or by the tabular area (see Table of Polygons, p. 36) and by one-third of the height, and the product is the content in equal terms of unity.

Note.—Where the whole height of the cone or pyramid can be obtained, of which the given frustum forms a part, the most simple method is first to find the whole contents, then the contents extending beyond the frustum, and subtracting the less from the greater, leaves the contents of the frustum required.

Application of the rules.

1. The perpendicular height A B of the frustum of a hexagonal pyramid C D E is $7\frac{1}{2}$ feet, and the breadth of each side at top and base equal $3\frac{3}{4}$ and $2\frac{1}{2}$ feet; required the solid contents of the frustum in cubic feet

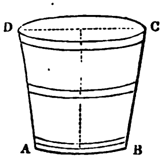


3·75 + 2·5 = 6·25, and 6·25 × 6·25 = 39·0625; then 3·75 × 2·5 = 9·375, and 39·0625 − 9·375 = 29·6875 × 2·598 (tabular area, p. 36) = 77·138 × 2·5 or ⅓ of the height = 192·845 cubic feet.

2. Required the solidity of the frustum of a cone, the top diameter of which is 7 inches, the base diameter 9½, and the perpendicular height 12.

$\overline{7 + 9\cdot5}^2 = 272\cdot25$, and 7 × 9·5 = 66·5; then 272·25 — 66·5 = 205·75 × ·7854 = 161·576 × 4 or ⅓ of the height = 646·3 cubic inches.

3. A vessel in the form of an inverted cone, as **A B C D**, is 5 feet in diameter at the top, 4 feet at the bottom, and 6 feet in depth; required its capacity in imperial gallons.



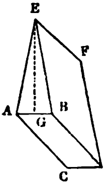
$\overline{5 + 4} = 9^2 = 81$, and 5 × 4 = 20; hence 81 − 20 = 61 × ·7854, and by 2 or ⅓ of the depth = 95·8188 cubic feet, and × 6·232 = 597·1427 gallons.

To find the solid contents of a wedge.

Rule.—To twice the length of the base add the length of the edge; multiply the sum by the breadth of the base, and by the perpendicular height from the base, and one-sixth of the product is the solid contents.

Application of the rule.

Required the solidity of a wedge in cubic inches, the base **A B C D** being 9 inches by 3½, the edge **E F**, 7 inches, and the perpendicular height **G E**, 15.



$$\frac{\overline{18 + 7} \times 3\cdot5 \times 15}{6} = 218\cdot75 \text{ cubic inches.}$$

To find the convex surface, the solidity, or the capacity of a sphere or globe.

Rule 1.—Multiply the square of the diameter by 3·1416, the product is the convex surface.

Rule 2.—Multiply the cube of the diameter by ·5236, the product is the solid contents.

Rule 3.—Multiply the cube of the diameter in feet by 3·263, or in inches by ·001888, the product is the capacity in imperial gallons.

Application of the rules.

1. Required the convex surface, the solidity, and the weight in cast iron, of a sphere or ball $10\frac{1}{2}$ inches in diameter.

$10{\cdot}5^2 \times 3{\cdot}1416 = 346{\cdot}3614$ square inches.
$10{\cdot}5^3 \times {\cdot}5236 = 606{\cdot}132$, &c. cubic inches, and
$606{\cdot}132 \times {\cdot}263$ (see Table of Approximations, p. 30)$=159{\cdot}4$ lbs.

2. A hollow or concave copper ball is required 8 inches diameter, and in weight just sufficient to sink to its centre in common water; what is the proper thickness of copper of which it must be made?

$$\left.\begin{array}{l} \text{Weight of a cubic inch of water} = {\cdot}03617 \text{ lbs.} \\ \quad ,, \qquad ,, \qquad \text{copper} = {\cdot}3225 \quad ,, \end{array}\right\} \text{see p. 113.}$$

$$\frac{8^3 \times {\cdot}5236 \times {\cdot}03617}{2} = 4{\cdot}84828 \text{ cub. in. of water to be displaced.}$$

$$\text{And } \frac{4{\cdot}84828}{{\cdot}3225} = 15{\cdot}0334 \text{ cubic inches of copper in the ball.}$$

Then $8^2 \times 3{\cdot}1416 = 201{\cdot}0624$, and $\frac{15{\cdot}0334}{201{\cdot}0624} = {\cdot}0747$ inch, the thickness of copper required.

${\cdot}0747 \times 16 = \frac{1}{16}$ of an inch full, or 3 lbs. copper to a square foot.

3. What diameter must I make a leaden ball, so as to weigh 72lbs.?

${\cdot}5236 \times {\cdot}4103 = {\cdot}21483308$, and $\frac{72}{{\cdot}21483308} = \sqrt[3]{340} = 6{\cdot}97$ inches diameter.

To ascertain the amount of convex surface, also the solid contents, of the segment of a globe.

Rule 1.—Multiply the circumference of the globe or sphere by the height of the segment, and the product is the convex surface.

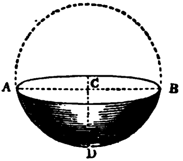
Rule 2.—To three times the square of the segment's radius add the square of its height, multiply the sum by the height, and by ·5236; the product is the solid contents.

Application of the Rules.

1. Required the number of square feet in the convex surface of a sphere, the height of which is 9½ feet, and the circumference of the sphere of which it is a part equal 70½ feet.

$$70{\cdot}5 \times 9{\cdot}5 = 669{\cdot}75 \text{ square feet.}$$

2. The radius A C or B C of the spherical segment A D B equal 48 inches, and the height D C equal 12 inches; required its solidity in cubic inches.



$48^2 \times 3 = 6912$, and $12^2 = 144$; then $\overline{6912 + 144} \times 12 \times {\cdot}5236 = 44334{\cdot}75$ cubic inches.

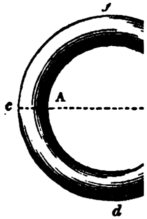
To find the convex surface and solidity of a cylindrical ring.

Rule 1.—To the sectional diameter of the ring add the inner diameter of the circle, multiply the sum by the sectional diameter, and by 9·8696; the product is the convex surface.

Rule 2.—To the sectional diameter of the ring add the inner diameter of the circle, multiply the sum by the square of the sectional diameter, and by 2·4674; the product is the solid contents.

Application of the Rules.

The inner diameter A B of the cylindric ring *c d e f* equal 18 feet, and the sectional diameter *c* A or B *e* equal 9 inches; required the convex surface and solidity of the ring.



18 feet × 12 = 216 inches, and

$\overline{216+9} \times 9 \times 9{\cdot}8696 = 19985{\cdot}94$ square inches.

$\overline{216+9} \times 9^2 \times 2{\cdot}4674 = 44968{\cdot}365$ cubic inches.

In the formation of a hoop or ring of wrou it is found in practice, that in bending the side or edge which forms the interior diamet hoop is upset or shortened, while at the s the exterior diameter is drawn or lengthened fore, the proper diameter by which to deter length of the iron in an unbent state, is the from centre to centre of the iron of which is composed: *hence the rule to determine t of the iron.* If it is the interior diameter of that is given, add the thickness of the iro the exterior diameter, subtract from the g meter the thickness of the iron, multiply th remainder by 3·1416, and the product is t of the iron, in equal terms of unity.

Supposing the interior diameter of a ho 32 inches, and the thickness of the iron must be the proper length of the iron, ind of any allowance for shutting?

$\overline{32+1{\cdot}25} = 33{\cdot}25 \times 3{\cdot}1416 = 104{\cdot}458$ inches

But the same is obtained simply by inspecti Table of Circumferences.

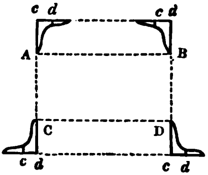
Thus, 33·25=2 ft. 9¼ in., opposite to which is 8 ft.

Again, let it be required to form a hoop of iron ⅞ inch in thickness, and 16½ inches outside diameter.

16·5—·875=15·625, or 1 foot 3⅝ inches;

opposite to which, in the Table of Circumferences, is 4 feet 1 inch, independent of any allowance for shutting.

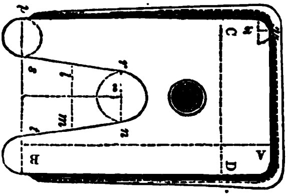
The length for angle iron, of which to form a ring of a given diameter, varies according to the strength of the iron at the root; and the rule is, for a ring with the flange outside, *add* to its required interior diameter, twice the extreme strength of the iron at the root; or, for a ring with the flange inside, *subtract* twice the extreme strength; and the sum or remainder is the diameter by which to determine the length of the angle iron. Thus, suppose two angle iron rings similar to the following be required, the exterior diameter A B, and interior diameter C D, each to be 1 foot 10½ inches, and the extreme strength of the iron at the root *c d*, *c d*, &c. ⅞ of an inch.



twice ⅞=1¾, and 1 ft. 10½ in. + 1¾=2 ft. ¼ in., opposite to which, in the Table of Circumferences, is 6 ft. 4¼ in., the length of the iron for C D; and 1 ft. 10½ in.—1¾=1 ft. 8¾ in., opposite to which is 5 ft. 5¼ in., the length of the iron for A B.

But observe as before, that the necessary allowance for shutting must be added to the length of the iron, in addition to the length as expressed by the Table.

Required the capacity in imperial gallons of a Locomotive Engine Tender tank, 2 feet 8 inches in depth, and its superficial dimensions the following, with reference to the annexed plan.



Length, or dist. between	A and B	=10 ft.	$2\frac{3}{4}$ in.	or,	122·75 in.
Breadth ,,	C ,, D	= 6 ,,	$7\frac{1}{2}$,,		79·5 ,,
Length ,,	*i* ,, *g*	= 3 ,,	$10\frac{3}{4}$,,		46·75 ,,
Mean breadth of coke space or	*lm* ,,	= 3 ,,	$1\frac{1}{4}$,,		37·25 ,,
Diameter of circle	*rn* ,,	= 2 ,,	$8\frac{1}{4}$,,		32·25 ,,
,, ,,	*ps* ,,	= 1 ,,	$6\frac{1}{2}$,,		18·5 ,,
Radius of back corners	*v x* ,,	=	4 ,,		4 ,,

Then, $122{\cdot}75 \times 79{\cdot}5 = 9758{\cdot}525$ square inches, as a rectangle.

And $18{\cdot}5^2 \times {\cdot}7854 = 268{\cdot}8$,, ,, area of circle formed by the two ends.

Total $\overline{10027{\cdot}325}$,, ,, from which deduct the area of the coke space, and the difference of area between the semicircle formed by the two back corners, and that of a rectangle of equal length and breadth;

Then $46{\cdot}75 \times 37{\cdot}25 = 1731{\cdot}4375$ area of *r*, *n*, *s*, *t*, in sq. ins.

$$\frac{32{\cdot}25^2 \times {\cdot}7854}{2} = 408{\cdot}4$$ area of half the circle *r n*.

Radius of back corners=4 inches;

consequently $8^2 \times {\cdot}7854 = 25{\cdot}13$, the semicircle's area;

and $8 \times 4 = 32 - 25{\cdot}13 = 6{\cdot}87$ inches taken off by rounding the corners.

Hence, $1731{\cdot}4375 + 408{\cdot}4 + 6{\cdot}87 = 2146{\cdot}707$, and

$10027{\cdot}325 - 2146{\cdot}707 = 7880{\cdot}618$ square inches, or whole area in plan,

$7880{\cdot}618 \times 32$ the depth$=252179{\cdot}776$ cubic inches,

and $252179{\cdot}776 \times {\cdot}003607$ (see Table of Approximations, page 30)$=909{\cdot}61245$ gallons.

PROPERTIES OF BODIES.

Tables combining the Specific Gravities and other Properties of Bodies. Water the standard of comparison, or 1000.

Names.	Specific gravity.	METALS.							
		Melting points in degrees of Fahrenheit.	Contraction in parts of an in. per lineal ft. from the fluid to the average temperature in solid state.	Ultimate cohesive strength of an inch sq. prism in tons.	Scale of wire-drawing ductility.	Scale of laminable ductility.	Ratio of hardness.	Scale as conductors of electricity.	Ratio of power in the conduction of heat.
Platinum	19500	3280	—	—	3	5	—	—	3·8
Pure Gold . . .	19258	2016	—	—	1	1	1·8	3	10·0
Mercury	13500	—	—	—	—	—	—	—	—
Lead	11352	612	·319	·81	8	7	1·0	6	1·8
Pure Silver . . .	10474	1873	—	—	2	2	2·4	2	9·7
Bismuth	9823	476	·156	1·45	—	—	2·0	—	—
Copper, cast . .	8788	1996	·193	8·51	—	—	—	—	—
,, wrought	8910	—	—	15·06	5	3	2·8	1	8·9
Brass, cast . . .	7824	1900	·210	8·01	—	—	to any degree	—	—
,, sheet . .	8396	—	—	12·23	6	6	—	—	8·6
Iron, cast	7264	2786	·125	7·87	—	—	to any degree	—	—
,, bar	7700	—	·137	25·00	4	8	4·7	4	3·7
Steel, soft . . .	7833	—	·133	58·91	—	—	—	—	—
,, hard . . .	7816	—	—	—	—	—	to any degree	—	—
Tin, cast	7291	442	·278	2·11	8	4	1·2	5	3·0
Zinc, cast . . .	7190	773	·329	5·05	7	8	1·6	7	3·6

Names.	STONES, EARTHS, &c.			
	Specific gravity.	Weight of a cubic foot in lbs.	Cubic feet in a ton.	Tons required to crush 1½-inch cubes.
Marble, average	2720	170·00	13	9·25
Granite, do. . .	2651	165·68	13⅓	6·2
Purbeck stone .	2601	162·56	13¾	9·0
Portland do. . .	2570	160·62	14	4·5
Bristol do. . . .	2554	159·62	14	—
Millstone	2484	155·25	14½	—
Paving stone . .	2415	150·93	14¾	5·7
Craigleith do. .	2362	147·62	15	5·0
Grindstone . . .	2143	133·93	16¾	6·6
Chalk, Brit. . .	2781	173·81	12¾	0·5
Brick	2000	125·00	17	0·8
Coal, Scotch . .	1300	81·15	27½	—
,, Newcastle	1270	79·37	27¼	—
,, Staffordsh.	1240	77·50	29	—
,, Cannel . .	1238	77·37	29	—

WOODS.

Names.	Specific gravity, water, 1000.	Average wt. of a cubic foot in lbs.	Cubic feet in a ton.	Ultimate cohesive strength of an inch square prism in lbs.	Comparative		
					Stiffness.	Strength.	Resilience.
English oak	934	58	38½	11880	100	100	100
Riga do.	872	54	41½	12888	93	108	125
Dantzic do........	756	47	48	12780	117	107	99
American do......	672	42	53	10253	114	86	64
Beech...........	852	48	45	12225	77	103	138
Alder	800	46	48½	9540	63	80	101
Plane	640	40	55	10935	78	92	108
Sycamore	604	38	59	9630	59	81	111
Chestnut.........	610	38	59	10656	67	89	118
Ash.............	845	52	43	14130	89	119	160
Elm.............	673	42	53	9720	78	82	86
Mahog. Spanish..	800	50	45	7560	73	67	61
,, Honduras	637	40	55	11475	93	96	99
Walnut..........	671	42	53	8800	49	74	111
Teak............	750	46	48½	12915	126	109	94
Poona...........	640	40	55	12350	99	104	82
African oak......	944	59	38	17200	101	144	138
Poplar..........	383	34	66	5928	44	50	57
Cedar	561	33	68	7420	28	62	106
Riga fir.........	753	47	48	9540	98	80	64
Memel do.	546	34	66	9540	114	80	56
Scotch do.	528	33	68	7110	55	60	65
Christ. wh^{te}. deal .	590	37	60	12346	104	104	104
Am^{n}. white spruce	551	34	66	10296	72	86	102
Yellow pine	461	28	80	11853	95	99	103
Pitch pine	660	41	54½	9796	73	82	92
Larch	530	31	72	12240	79	103	134
Cork...........	240	15	149	—	—	—	—

LIQUIDS.

Names.	Specific grav., water, 1000.	Weight of an imperial gall. in ℔s.
Acid, sulphuric	1850	18·5
„ nitric	1271	12·7
„ muriatic	1200	12·0
„ fluoric	1060	10·6
„ citric	1034	10·3
„ acetic	1062	10·6
Water from the Baltic	1015	10·2
Water from the Dead Sea	1240	12·4
Water from the Mediterranean	1029	10·3
Water, distilled	1000	10·0
Oils, expressed:		
„ linseed	940	9·4
„ sweet almond	932	9·3
„ whale	923	9·2
„ hempseed	926	9·3
„ olive	915	9·2
Oils, essential:		
„ cinnamon	1043	10·4
„ lavender	894	8·9
„ turpentine	870	8·7
„ amber	868	8·7
Alcohol	825	8·2
Ether, nitric	908	9·1
Proof spirit	922	9·2
Vinegar	1009	10·1

GASES.

Atmospheric air being the standard of comparison, or 1000.

Names.	Specific gravity.
Hydriodic acid gas	4340
Chlorine acid „	2500
Carbonic acid „	1527
Nitrous oxide „	1527
Cyanogen „	1805
Oxygen „	1111
Carbonic oxide „	972
Carburetted hydrogen gas	972
Prussic acid „	937
Ammoniacal do. „	590
Steam of water „	623
Hydrogen „	69

Weight of water at the common temperature:

1 cubic inch = ·03617 ℔.
1 „ foot = 62·5 „
1 „ „ = 6·25 imp. galls.
1·8 „ „ = 1 cwt.
1 cylindrical inch = ·02842 ℔.
1 „ foot = 49·1 „
1 „ „ = 5 imp. galls.
2·282 feet = 1 cwt.
11·2 imp. gallons = 1 cwt.
224 „ „ = 1 ton.

WEIGHT OF A LINEAL FOOT OF SQUARE AND ROUND BAR IRON IN POUNDS.

Square iron.				Round iron.			
Inches square.	lbs.	Inches square.	lbs.	Inches diam.	lbs.	Inches diam.	lbs.
1/4	·208	2	13·33	1/4	·163	2	10·47
5/16	·325	2 1/8	15·05	5/16	·255	2 1/8	11·82
3/8	·468	2 1/4	16·87	3/8	·368	2 1/4	13·25
7/16	·638	2 3/8	18·80	7/16	·501	2 3/8	14·76
1/2	·833	2 1/2	20·81	1/2	·654	2 1/2	16·36
9/16	1·05	2 5/8	22·96	9/16	·828	2 5/8	18·03
5/8	1·30	2 3/4	25·20	5/8	1·02	2 3/4	19·79
11/16	1·57	2 7/8	27·55	11/16	1·23	2 7/8	21·63
3/4	1·87	3	30·00	3/4	1·47	3	23·56
13/16	2·20	3 1/8	32·55	13/16	1·72	3 1/8	25·56
7/8	2·55	3 1/4	35·20	7/8	2·00	3 1/4	27·65
15/16	2·92	3 3/8	37·96	15/16	2·30	3 3/8	29·82
1	3·33	3 1/2	40·80	1	2·61	3 1/2	32·07
1 1/16	3·76	3 5/8	43·81	1 1/16	2·95	3 5/8	34·40
1 1/8	4·21	3 3/4	46·87	1 1/8	3·31	3 3/4	36·81
1 3/16	4·70	3 7/8	50·05	1 3/16	3·69	3 7/8	39·31
1 1/4	5·20	4	53·33	1 1/4	4·09	4	41·88
1 5/16	5·74	4 1/4	60·20	1 5/16	4·51	4 1/4	47·28
1 3/8	6·30	4 1/2	67·50	1 3/8	4·95	4 1/2	53·01
1 7/16	6·88	4 3/4	75·20	1 7/16	5·40	4 3/4	59·06
1 1/2	7·50	5	83·33	1 1/2	5·89	5	65·45
1 9/16	8·15	5 1/4	92·43	1 9/16	6·40	5 1/4	72·61
1 5/8	8·80	5 1/2	101·03	1 5/8	6·91	5 1/2	79·36
1 11/16	9·50	5 3/4	110·40	1 11/16	7·46	5 3/4	86·73
1 3/4	10·20	6	120·21	1 3/4	8·01	6	94·60
1 13/16	10·69	6 1/2	130·20	1 13/16	8·60	6 1/2	110·60
1 7/8	11·71	7	151·81	1 7/8	9·20	7	128·28
1 15/16	12·52	8	213·29	1 15/16	9·33	8	167·51

Note.—The elastic power or direct tension of bar iron medium quality per square inch of cross section equals 10 tons; and a bar is extended ·000096, or nearly one ten-thousandth part of its length for every ton of direct strain per square inch of its sectional area: note, also, that either of the metals,—iron, tin, or zinc,—at a red heat, possesses the property of decomposing water when in an aëriform state.

WEIGHT OF A LINEAL FOOT OF FLAT BAR IRON IN POUNDS.

Breadth in inches.	Thickness in parts of an inch.						
	¼	5/16	⅜	7/16	½	9/16	⅝
½	·417	·52	—	—	—	—	—
⅝	·52	·65	·78	·91	—	—	—
¾	·625	·785	·93	1·09	1·25	1·40	—
⅞	·725	·91	1·09	1·27	1·46	1·64	1·82
1	·834	1·04	1·25	1·45	1·67	1·87	2·08
1⅛	·937	1·17	1·40	1·64	1·87	2·10	2·34
1¼	1·04	1·30	1·56	1·82	2·08	2·34	2·60
1⅜	1·14	1·43	1·71	2·00	2·29	2·57	2·86
1½	1·25	1·56	1·87	2·18	2·50	2·81	3·12
1⅝	1·35	1·69	2·03	2·36	2·70	3·04	3·38
1¾	1·45	1·82	2·18	2·55	2·91	3·28	3·64
1⅞	1·56	1·95	2·34	2·73	3·12	3·51	3·90
2	1·66	2·08	2·50	2·91	3·33	3·75	4·16
2⅛	1·77	2·21	2·65	3·09	3·54	3·98	4·42
2¼	1·87	2·34	2·81	3·28	3·75	4·21	4·68
2⅜	1·97	2·47	2·96	3·46	3·95	4·45	4·94
2½	2·08	2·60	3·12	3·64	4·16	4·68	5·20
2⅝	2·18	2·73	3·28	3·82	4·37	4 92	5·46
2¾	2·29	2·86	3·43	4·01	4·58	5·15	5·72
2⅞	2·39	2·99	3·59	4·19	4·79	5·39	5·98
3	2·50	3·12	3·75	4·37	5·00	5·62	6·25
3¼	2·70	3·38	4·06	4·73	5·41	6·09	6·77
3½	2·91	3·64	4·37	5·10	5·83	6·56	7·29
3¾	3·12	3·90	4·68	5·46	6·25	7·03	7·81
4	3·33	4·16	5·00	5·83	6·66	7·50	8·33
4¼	3·54	4·42	5·31	6·19	7·08	7·96	8·85
4½	3·75	4·68	5·62	6·56	7·50	8·43	9·37
4¾	3·95	4·94	5·93	6·92	7·91	8·90	9·89
5	4·17	5·20	6·25	7·29	8·33	9·37	10·41
5¼	4·37	5·46	6·56	7·65	8·75	9·84	10·93
5½	4·58	5·72	6·87	8·02	9·16	10·31	11·45
5¾	4·79	5·98	7·18	8·38	9·58	10·78	11·97
6	5·	6·26	7·50	8·75	10·00	11·25	12·50

WEIGHT OF FLAT BAR IRON—*continued.*

Breadth in inches.	Thickness in parts of an inch.						
	$\frac{11}{16}$	¾	$\frac{13}{16}$	⅞	$\frac{15}{16}$	1	1⅛
1	2·29	—	—	—	—	—	—
1⅛	2·57	2·81	3·04	—	—	—	—
1¼	2·86	3·12	3·38	3·64	3·90	—	—
1⅜	3·15	3·43	3·72	4·01	4·29	4·58	—
1½	3·43	3·75	4·06	4·37	4·68	5·00	5·62
1⅝	3·72	4·06	4·40	4·73	5·07	5·41	6·08
1¾	4·01	4·37	4·73	5·10	5·46	5·83	6·56
1⅞	4·29	4·68	5·07	5·46	5·85	6·25	7·02
2	4·58	5·00	5·41	5·83	6·25	6·66	7·50
2⅛	4·86	5·31	5·75	6·19	6·64	7·08	7·96
2¼	5·15	5·62	6·09	6·56	7·03	7·50	8·43
2⅜	5·44	5·93	6·43	6·92	7·42	7·91	8·90
2½	5·72	6·25	6·77	7·29	7·81	8·33	9·36
2⅝	6·01	6·56	7·10	7·65	8·20	8·75	9·84
2¾	6·30	6·87	7·44	8·02	8·59	9·16	10·30
2⅞	6·58	7·18	7·78	8·38	8·98	9·58	10·78
3	6·87	7·50	8·12	8·75	9·37	10·00	11·25
3¼	7·44	8·12	8·80	9·47	10·15	10·83	12·18
3½	8·02	8·75	9·47	10·20	10·93	11·66	13·12
3¾	8·59	9·37	10·15	10·93	11·71	12·50	14·06
4	9·16	10·00	10·83	11·66	12·50	13·33	15·00
4¼	9·73	10·62	11·51	12·39	13·28	14·16	15·92
4½	10·31	11·25	12·18	13·12	14·06	15·00	16·86
4¾	10·88	11·87	12·86	13·85	14·84	15·83	17·80
5	11·45	12·50	13·54	14·58	15·62	16·66	18·75
5¼	12·03	13·12	14·21	15·31	16·40	17·50	19·68
5½	12·60	13·75	14·89	16·04	17·18	18·33	20·62
5¾	13·17	14·37	15·57	16·77	17·96	19·16	21·56
6	13·75	15·00	16·25	17·50	18·75	20·00	22·50
6½	14·88	16·24	17·60	18·95	20·30	21·66	24·36
7	16·04	17·50	18·94	20·41	21·86	23·33	26·24
7½	17·18	18·74	20·30	21·86	23·42	25·00	28·12
8	18·32	20·00	21·76	23·32	25·00	26·66	30·00

WEIGHT OF FLAT BAR IRON—*continued.*

Breadth in inches.	Thickness in inches.					
	1¼	1⅜	1½	1¾	2	2½
1½	6·24	6·86	—	—	—	—
1¾	7·28	8·02	8·74	—	—	—
2	8·32	9·16	10·00	11·66	—	—
2¼	9·36	10·30	11·24	13·12	15·00	—
2½	10·40	11·44	12·50	14·58	16·66	—
2¾	11·44	12·60	13·74	16·04	18·32	22·88
3	12·50	13·74	15·00	17·50	20·00	25·00
3¼	13·54	14·88	16·24	18·94	21·66	27·08
3½	14·58	16·04	17·50	20·40	23·32	29·16
3¾	15·62	17·18	18·74	21·86	25·00	31·24
4	16·66	18·32	20·00	23·32	26·66	33·32
4¼	17·70	19·46	21·24	25·78	28·32	35·40
4½	18·74	20·62	22·50	26·24	30·00	37·48
4¾	19·78	21·76	23·74	27·70	31·67	39·56
5	20·82	22·90	25·00	29·16	33·32	41·64
5¼	21·86	24·06	26·24	30·62	35·00	43·72
5½	22·90	25·20	27·50	32·08	36·66	45·80
5¾	23·94	26·34	28·74	33·54	38·32	47·88
6	25·00	27·50	30·00	35·00	40·00	50·00
6½	27·08	29·76	32·48	37·88	43·32	54·16
7	29·16	32·08	35·00	40·80	46·64	58·32
7½	31·24	34·36	37·48	43·72	50·00	62·48
8	33·32	36·64	40·00	46·64	53·32	66·64
8½	35·40	38·92	42·48	51·56	56·64	70·80
9	37·48	41·24	45·00	52·48	60·00	74·96

MECHANICAL TABLES

FOR THE USE OF OPERATIVE SMITHS, MILLWRIGHTS, AND ENGINEERS.

The following Tables, originally dedicated to 'the National Association of the Forgers of Iron-Work,' are, with permission, added to the present edition: they will be found extremely useful to Smiths generally, and are accompanied by Observations and Practical Examples.

TABLE I.*

DIAMETERS AND CIRCUMFERENCES OF CIRC

from One Inch to upwards of Twenty Feet, advancing by a

Diameter.	Circumference.		Diameter.	Circumference.		Diameter.		Circumference.		Diameter	
In.	Ft.	In.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In
1	0	3⅛	5	1	3⅝	0	9	2	4¼	1	1
1⅛	0	3½	5⅛	1	4	0	9⅛	2	4⅝	1	1
1¼	0	3⅞	5¼	1	4⅜	0	9¼	2	5	1	1
1⅜	0	4¼	5⅜	1	4⅞	0	9⅜	2	5⅜	1	1
1½	0	4⅝	5½	1	5¼	0	9½	2	5¾	1	1
1⅝	0	5	5⅝	1	5⅝	0	9⅝	2	6⅛	1	1
1¾	0	5½	5¾	1	6	0	9¾	2	6⅝	1	1
1⅞	0	5⅞	5⅞	1	6⅜	0	9⅞	2	7	1	1
2	0	6¼	6	1	6¾	0	10	2	7⅜	1	2
2⅛	0	6⅝	6⅛	1	7⅛	0	10⅛	2	7¾	1	2
2¼	0	7	6¼	1	7⅝	0	10¼	2	8⅛	1	2
2⅜	0	7⅜	6⅜	1	8	0	10⅜	2	8½	1	2
2½	0	7¾	6½	1	8⅜	0	10½	2	8⅞	1	2
2⅝	0	8⅛	6⅝	1	8¾	0	10⅝	2	9⅜	1	2
2¾	0	8⅝	6¾	1	9⅛	0	10¾	2	9¾	1	2
2⅞	0	9	6⅞	1	9½	0	10⅞	2	10⅛	1	2
3	0	9⅜	7	1	9⅞	0	11	2	10½	1	3
3⅛	0	9¾	7⅛	1	10⅜	0	11⅛	2	10⅞	1	3
3¼	0	10⅛	7¼	1	10¾	0	11¼	2	11¼	1	3¼
3⅜	0	10½	7⅜	1	11⅛	0	11⅜	2	11⅝	1	3
3½	0	10⅞	7½	1	11½	0	11½	3	0	1	3
3⅝	0	11⅜	7⅝	1	11⅞	0	11⅝	3	0½	1	3
3¾	0	11¾	7¾	2	0¼	0	11¾	3	0⅞	1	3¾
3⅞	1	0⅛	7⅞	2	0⅝	0	11⅞	3	1¼	1	3⅞
4	1	0½	8	2	1⅛	1	0	3	1⅝	1	4
4⅛	1	0⅞	8⅛	2	1½	1	0⅛	3	2	1	4⅛
4¼	1	1¼	8¼	2	1⅞	1	0¼	3	2⅜	1	4¼
4⅜	1	1⅝	8⅜	2	2¼	1	0⅜	3	2⅞	1	4⅜
4½	1	2⅛	8½	2	2⅝	1	0½	3	3¼	1	4½
4⅝	1	2½	8⅝	2	3	1	0⅝	3	3⅝	1	4⅝
4¾	1	2⅞	8¾	2	3⅜	1	0¾	3	4	1	4¾
4⅞	1	3¼	8⅞	2	3⅞	1	0⅞	3	4⅜	1	4⅞

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* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In
1	5	4	5⅜	1	9⅜	5	7⅛	2	1¾	6	8⅞	2	6⅛	7	10
1	5⅛	4	5¾	1	9½	5	7½	2	1⅞	6	9¼	2	6¼	7	11
1	5¼	4	6⅛	1	9⅝	5	8	2	2	6	9⅝	2	6⅜	7	11
1	5⅜	4	6½	1	9¾	5	8⅜	2	2⅛	6	10	2	6½	7	11
1	5½	4	6⅞	1	9⅞	5	8¾	2	2¼	6	10⅜	2	6⅝	8	0
1	5⅝	4	7⅜	1	10	5	9	2	2⅜	6	10¾	2	6¾	8	0
1	5¾	4	7¾	1	10⅛	5	9½	2	2½	6	11¼	2	6⅞	8	0
1	5⅞	4	8⅛	1	10¼	5	9⅞	2	2⅝	6	11⅝	2	7	8	1
1	6	4	8½	1	10⅜	5	10¼	2	2¾	7	0	2	7⅛	8	1
1	6⅛	4	8⅞	1	10½	5	10⅝	2	2⅞	7	0⅜	2	7¼	8	2
1	6¼	4	9¼	1	10⅝	5	11	2	3	7	0¾	2	7⅜	8	2
1	6⅜	4	9⅝	1	10¾	5	11⅜	2	3⅛	7	1⅛	2	7½	8	2
1	6½	4	10	1	10⅞	5	11¾	2	3¼	7	1½	2	7⅝	8	3
1	6⅝	4	10⅜	1	11	6	0¼	2	3⅜	7	2	2	7¾	8	3
1	6¾	4	10⅞	1	11⅛	6	0⅝	2	3½	7	2⅜	2	7⅞	8	4
1	6⅞	4	11¼	1	11¼	6	1	2	3⅝	7	2¾	2	8	8	4
1	7	4	11⅝	1	11⅜	6	1⅜	2	3¾	7	3⅛	2	8⅛	8	4
1	7⅛	5	0	1	11½	6	1¾	2	3⅞	7	3½	2	8¼	8	5
1	7¼	5	0⅜	1	11⅝	6	2⅛	2	4	7	3⅞	2	8⅜	8	5
1	7⅜	5	0⅞	1	11¾	6	2½	2	4⅛	7	4¼	2	8½	8	6
1	7½	5	1¼	1	11⅞	6	3	2	4¼	7	4¾	2	8⅝	8	6
1	7⅝	5	1⅝	2	0	6	3⅜	2	4⅜	7	5⅛	2	8¾	8	6
1	7¾	5	2	2	0⅛	6	3¾	2	4½	7	5½	2	8⅞	8	7
1	7⅞	5	2⅜	2	0¼	6	4⅛	2	4⅝	7	5⅞	2	9	8	7
1	8	5	2¾	2	0⅜	6	4½	2	4¾	7	6¼	2	9⅛	8	8
1	8⅛	5	3⅛	2	0½	6	4⅞	2	4⅞	7	6⅝	2	9¼	8	8
1	8¼	5	3⅝	2	0⅝	6	5¼	2	5	7	7	2	9⅜	8	8
1	8⅜	5	4	2	0¾	6	5¾	2	5⅛	7	7½	2	9½	8	9
1	8½	5	4⅜	2	0⅞	6	6⅛	2	5¼	7	7⅞	2	9⅝	8	9
1	8⅝	5	4¾	2	1	6	6½	2	5⅜	7	8¼	2	9¾	8	10
1	8¾	5	5⅛	2	1⅛	6	6⅞	2	5½	7	8⅝	2	9⅞	8	10
1	8⅞	5	5½	2	1¼	6	7¼	2	5⅝	7	9	2	10	8	10
1	9	5	5⅞	2	1⅜	6	7⅝	2	5¾	7	9⅜	2	10⅛	8	11
1	9⅛	5	6⅜	2	1½	6	8	2	5⅞	7	9¾	2	10¼	8	11
1	9¼	5	6¾	2	1⅝	6	8½	2	6	7	10⅛	2	10⅜	8	11

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
2	10½	9	0⅜	3	2⅞	10	2⅛	3	7⅛	11	3⅜	3	11½	12	5¼
2	10⅝	9	0¾	3	3	10	2½	3	7¼	11	3⅞	3	11⅝	12	5½
2	10¾	9	1⅛					3	7⅜	11	4¼	3	11¾	12	6
2	10⅞	9	1½	3	3⅛	10	2⅞	3	7½	11	4⅝	3	11⅞	12	6⅜
2	11	9	1⅞	3	3¼	10	3⅛	3	7⅝	11	5	4	0	12	6¾
2	11⅛	9	2¼	3	3⅜	10	3⅝	3	7¾	11	5⅜	4	0⅛	12	7⅛
2	11¼	9	2⅝	3	3½	10	4	3	7⅞	11	5¾	4	0¼	12	7½
2	11⅜	9	3	3	3⅝	10	4½	3	8	11	6⅛	4	0⅜	12	7⅞
2	11½	9	3½	3	3¾	10	4⅞	3	8⅛	11	6½	4	0½	12	8¼
2	11⅝	9	3⅞	3	3⅞	10	5¼	3	8¼	11	7	4	0⅝	12	8¾
2	11¾	9	4¼	3	4	10	5⅝	3	8⅜	11	7⅜	4	0¾	12	9⅛
2	11⅞	9	4⅝	3	4⅛	10	6	3	8½	11	7¾	4	0⅞	12	9½
3	0	9	5	3	4¼	10	6⅜	3	8⅝	11	8⅛	4	1	12	9⅞
3	0⅛	9	5⅜	3	4⅜	10	6¾	3	8¾	11	8½	4	1⅛	12	10¼
3	0¼	9	5⅞	3	4½	10	7⅛	3	8⅞	11	8⅞	4	1¼	12	10⅝
3	0⅜	9	6¼	3	4⅝	10	7⅝	3	9	11	9¼	4	1⅜	12	11
3	0½	9	6⅝	3	4¾	10	8	3	9⅛	11	9¾	4	1½	12	11½
3	0⅝	9	7	3	4⅞	10	8⅜	3	9¼	11	10⅛	4	1⅝	12	11⅞
3	0¾	9	7⅜	3	5	10	8¾	3	9⅜	11	10½	4	1¾	13	0¼
3	0⅞	9	7¾	3	5⅛	10	9⅛	3	9½	11	10⅞	4	1⅞	13	0⅝
3	1	9	8⅛	3	5¼	10	9½	3	9⅝	11	11¼	4	2	13	1
3	1⅛	9	8⅝	3	5⅜	10	9⅞	3	9¾	11	11⅝	4	2⅛	13	1½
3	1¼	9	9	3	5½	10	10⅜	3	9⅞	12	0	4	2¼	13	1⅞
3	1⅜	9	9⅜	3	5⅝	10	10¾	3	10	12	0½	4	2⅜	13	2¼
3	1½	9	9¾	3	5¾	10	11⅛	3	10⅛	12	0⅞	4	2½	13	2⅝
3	1⅝	9	10⅛	3	5⅞	10	11½	3	10¼	12	1¼	4	2⅝	13	3
3	1¾	9	10½	3	6	10	11⅞	3	10⅜	12	1⅝	4	2¾	13	3⅜
3	1⅞	9	10⅞	3	6⅛	11	0¼	3	10½	12	2	4	2⅞	13	3¾
3	2	9	11⅜	3	6¼	11	0⅝	3	10⅝	12	2⅜	4	3	13	4⅛
3	2⅛	9	11¾	3	6⅜	11	1⅛	3	10¾	12	2¾	4	3⅛	13	4½
3	2¼	10	0⅛	3	6½	11	1½	3	10⅞	12	3¼	4	3¼	13	5
3	2⅜	10	0½	3	6⅝	11	1⅞	3	11	12	3⅝	4	3⅜	13	5⅜
3	2½	10	0⅞	3	6¾	11	2¼	3	11⅛	12	4	4	3½	13	5¾
3	2⅝	10	1¼	3	6⅞	11	2⅝	3	11¼	12	4⅜	4	3⅝	13	6⅛
3	2¾	10	1⅝	3	7	11	3	3	11⅜	12	4¾	4	3¾	13	6½

Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
13	6⅞	4	8⅛	14	8¼	5	0½	15	10	5	4⅞	16	11¾
13	7¼	4	8¼	14	8⅝	5	0⅝	15	10⅜	5	5	17	0⅛
		4	8⅜	14	9	5	0¾	15	10¾				
13	7⅝	4	8½	14	9½	5	0⅞	15	11⅛	5	5⅛	17	0⅝
13	8⅛	4	8⅝	14	9⅞	5	1	15	11⅝	5	5¼	17	1
13	8½	4	8¾	14	10¼					5	5⅜	17	1⅜
13	8⅞	4	8⅞	14	10⅝	5	1⅛	16	0	5	5½	17	1¾
13	9¼	4	9	14	11	5	1¼	16	0⅜	5	5⅝	17	2⅛
13	9⅝					5	1⅜	16	0¾	5	5¾	17	2½
13	10	4	9⅛	14	11⅜	5	1½	16	1⅛	5	5⅞	17	2⅞
13	10½	4	9¼	14	11¾	5	1⅝	16	1½	5	6	17	3¼
		4	9⅜	15	0⅛	5	1¾	16	1⅞				
13	10⅞	4	9½	15	0⅝	5	1⅞	16	2⅜	5	6⅛	17	3⅝
13	11¼	4	9⅝	15	1	5	2	16	2¾	5	6¼	17	4⅛
13	11⅝	4	9¾	15	1⅜					5	6⅜	17	4½
14	0	4	9⅞	15	1¾	5	2⅛	16	3⅛	5	6½	17	4⅞
14	0⅜	4	10	15	2⅛	5	2¼	16	3½	5	6⅝	17	5¼
14	0⅞					5	2⅜	16	3⅞	5	6¾	17	5⅝
14	1¼	4	10⅛	15	2½	5	2½	16	4¼	5	6⅞	17	6
14	1⅝	4	10¼	15	2⅞	5	2⅝	16	4⅝	5	7	17	6⅜
		4	10⅜	15	3⅜	5	2¾	16	5⅛				
		4	10½	15	3¾	5	2⅞	16	5½				
14	2	4	10⅝	15	4⅛	5	3	16	5⅞	5	7⅛	17	6⅞
14	2⅜	4	10¾	15	4½					5	7¼	17	7¼
14	2¾	4	10⅞	15	4⅞	5	3⅛	16	6¼	5	7⅜	17	7⅝
14	3⅛	4	11	15	5¼	5	3¼	16	6⅝	5	7½	17	8
14	3½					5	3⅜	16	7	5	7⅝	17	8⅜
14	4	4	11⅛	15	5⅝	5	3½	16	7⅜	5	7¾	17	8¾
14	4⅜	4	11¼	15	6⅛	5	3⅝	16	7⅞	5	7⅞	17	9⅛
14	4¾	4	11⅜	15	6½	5	3¾	16	8¼	5	8	17	9⅝
		4	11½	15	6⅞	5	3⅞	16	8⅝				
14	5⅛	4	11⅝	15	7¼	5	4	16	9	5	8⅛	17	10
14	5½	4	11¾	15	7⅝					5	8¼	17	10⅜
14	5⅞	4	11⅞	15	8	5	4⅛	16	9⅝	5	8⅜	17	10¾
14	6¼	5	0	15	8⅜	5	4¼	16	9¾	5	8½	17	11⅛
14	6¾					5	4⅜	16	10⅛	5	8⅝	17	11½
14	7⅛	5	0⅛	15	8⅞	5	4½	16	10⅝	5	8¾	17	11⅞
14	7½	5	0¼	15	9¼	5	4⅝	16	11	5	8⅞	18	0⅜
14	7⅞	5	0⅜	15	9⅝	5	4¾	16	11⅜	5	9	18	0¾

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circu	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	
5	9⅛	18	1⅛	6	1½	19	2⅞	6	5⅞	20	4⅝	6	10⅛	21	
5	9¼	18	1½	6	1⅝	19	3¼	6	6	20	5	6	10¼	21	
5	9⅜	18	1⅞	6	1¾	19	3⅝	6	6⅛	20	5⅜	6	10⅜	21	
5	9½	18	2¼	6	1⅞	19	4	6	6¼	20	5¾	6	10½	21	
5	9⅝	18	2⅝	6	2	19	4⅜	6	6⅜	20	6⅛	6	10⅝	21	
5	9¾	18	3	6	2⅛	19	4¾	6	6½	20	6½	6	10¾	21	
5	9⅞	18	3½	6	2¼	19	5¼	6	6⅝	20	7	6	10⅞	21	
5	10	18	3⅞	6	2⅜	19	5⅝	6	6¾	20	7⅜	6	11	21	
5	10⅛	18	4¼	6	2½	19	6	6	6⅞	20	7¾	6	11⅛	21	
5	10¼	18	4⅝	6	2⅝	19	6⅜	6	7	20	8⅛	6	11¼	21	
5	10⅜	18	5	6	2¾	19	6¾	6	7⅛	20	8½	6	11⅜	21	
5	10½	18	5⅜	6	2⅞	19	7⅛	6	7¼	20	8⅞	6	11½	21	
5	10⅝	18	5⅞	6	3	19	7½	6	7⅜	20	9¼	6	11⅝	21	
5	10¾	18	6¼	6	3⅛	19	8	6	7½	20	9¾	6	11¾	21	
5	10⅞	18	6⅝	6	3¼	19	8⅜	6	7⅝	20	10⅛	6	11⅞	21	
5	11	18	7	6	3⅜	19	8¾	6	7¾	20	10½	7	0	21	
5	11⅛	18	7⅜	6	3½	19	9⅛	6	7⅞	20	10⅞	7	0⅛	22	
5	11¼	18	7¾	6	3⅝	19	9½	6	8	20	11¼	7	0¼	22	
5	11⅜	18	8⅛	6	3¾	19	9⅞	6	8⅛	20	11⅝	7	0⅜	22	
5	11½	18	8½	6	3⅞	19	10¼	6	8¼	21	0	7	0½	22	
5	11⅝	18	9	6	4	19	10¾	6	8⅜	21	0½	7	0⅝	22	
5	11¾	18	9⅜	6	4⅛	19	11⅛	6	8½	21	0⅞	7	0¾	22	
5	11⅞	18	9¾	6	4¼	19	11½	6	8⅝	21	1¼	7	0⅞	22	
6	0	18	10⅛	6	4⅜	19	11⅞	6	8¾	21	1⅝	7	1	22	
6	0⅛	18	10½	6	4½	20	0¼	6	8⅞	21	2	7	1⅛	22	
6	0¼	18	10⅞	6	4⅝	20	0⅝	6	9	21	2⅜	7	1¼	22	
6	0⅜	18	11¼	6	4¾	20	1	6	9⅛	21	2⅞	7	1⅜	22	
6	0½	18	11¾	6	4⅞	20	1½	6	9¼	21	3¼	7	1½	22	
6	0⅝	19	0⅛	6	5	20	1⅞	6	9⅜	21	3⅝	7	1⅝	22	
6	0¾	19	0½	6	5⅛	20	2¼	6	9½	21	4	7	1¾	22	
6	0⅞	19	0⅞	6	5¼	20	2⅝	6	9⅝	21	4⅜	7	1⅞	22	
6	1	19	1¼	6	5⅜	20	3	6	9¾	21	4¾	7	2	22	
6	1⅛	19	1⅝	6	5½	20	3⅜	6	9⅞	21	5⅛	7	2⅛	22	
6	1¼	19	2	6	5⅝	20	3¾	6	10	21	5½	7	2¼	22	
6	1⅜	19	2½	6	5¾	20	4¼					7	2⅜	22	

CIRCLES ADVANCING BY AN EIGHTH.

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
7	2½	22	7⅝
7	2⅝	22	8⅛
7	2¾	22	8½
7	2⅞	22	8⅞
7	3	22	9¼
7	3⅛	22	9⅝
7	3¼	22	10
7	3⅜	22	10⅜
7	3½	22	10⅞
7	3⅝	22	11¼
7	3¾	22	11⅝
7	3⅞	23	0
7	4	23	0⅜
7	4⅛	23	0¾
7	4¼	23	1⅛
7	4⅜	23	1⅝
7	4½	23	2
7	4⅝	23	2⅜
7	4¾	23	2¾
7	4⅞	23	3⅛
7	5	23	3½
7	5⅛	23	3⅞
7	5¼	23	4⅜
7	5⅜	23	4¾
7	5½	23	5⅛
7	5⅝	23	5½
7	5¾	23	5⅞
7	5⅞	23	6¼
7	6	23	6⅝
7	6⅛	23	7⅛
7	6¼	23	7½
7	6⅜	23	7⅞
7	6½	23	8¼
7	6⅝	23	8⅝
7	6¾	23	9
7	6⅞	23	9⅜
7	7	23	9⅞
7	7⅛	23	10¼
7	7¼	23	10⅝
7	7⅜	23	11
7	7½	23	11⅜
7	7⅝	23	11¾
7	7¾	24	0⅛
7	7⅞	24	0⅝
7	8	24	1
7	8⅛	24	1⅜
7	8¼	24	1¾
7	8⅜	24	2⅛
7	8½	24	2½
7	8⅝	24	2⅞
7	8¾	24	3⅜
7	8⅞	24	3¾
7	9	24	4⅛
7	9⅛	24	4½
7	9¼	24	4⅞
7	9⅜	24	5¼
7	9½	24	5⅝
7	9⅝	24	6⅛
7	9¾	24	6½
7	9⅞	24	6⅞
7	10	24	7¼
7	10⅛	24	7⅝
7	10¼	24	8
7	10⅜	24	8⅜
7	10½	24	8⅞
7	10⅝	24	9¼
7	10¾	24	9⅝
7	10⅞	24	10
7	11	24	10⅜
7	11⅛	24	10¾
7	11¼	24	11⅛
7	11⅜	24	11½
7	11½	25	0
7	11⅝	25	0⅜
7	11¾	25	0¾
7	11⅞	25	1⅛
8	0	25	1½
8	0⅛	25	1⅞
8	0¼	25	2⅜
8	0⅜	25	2¾
8	0½	25	3⅛
8	0⅝	25	3½
8	0¾	25	3⅞
8	0⅞	25	4¼
8	1	25	4⅝
8	1⅛	25	5⅛
8	1¼	25	5½
8	1⅜	25	5⅞
8	1½	25	6¼
8	1⅝	25	6⅝
8	1¾	25	7
8	1⅞	25	7⅜
8	2	25	7⅞
8	2⅛	25	8¼
8	2¼	25	8⅝
8	2⅜	25	9
8	2½	25	9⅜
8	2⅝	25	9¾
8	2¾	25	10⅛
8	2⅞	25	10½
8	3	25	11
8	3⅛	25	11⅜
8	3¼	25	11¾
8	3⅜	26	0⅛
8	3½	26	
8	3⅝	26	
8	3¾	26	
8	3⅞	26	
8	4	26	
8	4⅛	26	
8	4¼	26	
8	4⅜	26	
8	4½	26	
8	4⅝	26	
8	4¾	26	
8	4⅞	26	
8	5	26	
8	5⅛	26	
8	5¼	26	
8	5⅜	26	
8	5½	26	
8	5⅝	26	
8	5¾	26	
8	5⅞	26	
8	6	26	
8	6⅛	26	
8	6¼	26	
8	6⅜	26	
8	6½	26	1
8	6⅝	26	1
8	6¾	26	1
8	6⅞	26	1
8	7	26	1
8	7⅛	26	1
8	7¼	27	
8	7⅜	27	
8	7½	27	
8	7⅝	27	
8	7¾	27	

Diam.		Circum.	
Ft.	In.	Ft.	In.
8	7⅞	27	2¼
8	8	27	2⅝
8	8⅛	27	3
8	8¼	27	3½
8	8⅜	27	3⅞
8	8½	27	4¼
8	8⅝	27	4⅝
8	8¾	27	5
8	8⅞	27	5⅜
8	9	27	5¾
8	9⅛	27	6¼
8	9¼	27	6⅝
8	9⅜	27	7
8	9½	27	7⅜
8	9⅝	27	7¾
8	9¾	27	8⅛
8	9⅞	27	8½
8	10	27	9
8	10⅛	27	9⅜
8	10¼	27	9¾
8	10⅜	27	10⅛
8	10½	27	10½
8	10⅝	27	10⅞
8	10¾	27	11¼
8	10⅞	27	11¾
8	11	28	0⅛
8	11⅛	28	0½
8	11¼	28	0⅞
8	11⅜	28	1¼
8	11½	28	1⅝
8	11⅝	28	2
8	11¾	28	2½
8	11⅞	28	2⅞
9	0	28	3¼
9	0⅛	28	3⅝
9	0¼	28	4
9	0⅜	28	4⅜
9	0½	28	4¾
9	0⅝	28	5¼
9	0¾	28	5⅝
9	0⅞	28	6
9	1	28	6⅜
9	1⅛	28	6¾
9	1¼	28	7⅛
9	1⅜	28	7½
9	1½	28	8
9	1⅝	28	8⅜
9	1¾	28	8¾
9	1⅞	28	9⅛
9	2	28	9½
9	2⅛	28	9⅞
9	2¼	28	10¼
9	2⅜	28	10¾
9	2½	28	11⅛
9	2⅝	28	11½
9	2¾	28	11⅞
9	2⅞	29	0¼
9	3	29	0⅝
9	3⅛	29	1
9	3¼	29	1½
9	3⅜	29	1⅞
9	3½	29	2¼
9	3⅝	29	2⅝
9	3¾	29	3
9	3⅞	29	3⅜
9	4	29	3¾
9	4⅛	29	4¼
9	4¼	29	4⅝
9	4⅜	29	5
9	4½	29	5⅜
9	4⅝	29	5¾
9	4¾	29	6⅛
9	4⅞	29	6½
9	5	29	7
9	5⅛	29	7⅜
9	5¼	29	7¾
9	5⅜	29	8⅛
9	5½	29	8½
9	5⅝	29	8⅞
9	5¾	29	9¼
9	5⅞	29	9¾
9	6	29	10⅛
9	6⅛	29	10½
9	6¼	29	10⅞
9	6⅜	29	11¼
9	6½	29	11⅝
9	6⅝	30	0
9	6¾	30	0½
9	6⅞	30	0⅞
9	7	30	1¼
9	7⅛	30	1⅝
9	7¼	30	2
9	7⅜	30	2⅜
9	7½	30	2¾
9	7⅝	30	3⅛
9	7¾	30	3⅝
9	7⅞	30	4
9	8	30	4⅜
9	8⅛	30	4¾
9	8¼	30	5⅛
9	8⅜	30	5½
9	8½	30	6
9	8⅝	30	6⅜
9	8¾	30	6¾
9	8⅞	30	
9	9	30	
9	9⅛	30	
9	9¼	30	
9	9⅜	30	
9	9½	30	
9	9⅝	30	
9	9¾	30	
9	9⅞	30	
9	10	30	
9	10⅛	30	
9	10¼	30	
9	10⅜	30	
9	10½	31	
9	10⅝	31	
9	10¾	31	
9	10⅞	31	
9	11	31	
9	11⅛	31	
9	11¼	31	
9	11⅜	31	
9	11½	31	
9	11⅝	31	
9	11¾	31	
9	11⅞	31	
10	0	31	
10	0⅛	31	
10	0¼	31	
10	0⅜	31	
10	0½	31	
10	0⅝	31	
10	0¾	31	
10	0⅞	31	
10	1	31	

iam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
	1⅛	31	8½	10	5½	32	10¼	10	9⅞	34	0	11	2⅛	35	1¼
	1¼	31	8⅞	10	5⅝	32	10⅝	10	10	34	0⅜	11	2¼	35	1¾
	1⅜	31	9¼	10	5¾	32	11					11	2⅜	35	2⅛
	1½	31	9⅝	10	5⅞	32	11⅜	10	10⅛	34	0¾	11	2½	35	2½
	1⅝	31	10	10	6	32	11¾	10	10¼	34	1⅛	11	2⅝	35	2⅞
	1¾	31	10⅜					10	10⅜	34	1½	11	2¾	35	3¼
	1⅞	31	10⅞	10	6⅛	33	0⅛	10	10½	34	1⅞	11	2⅞	35	3⅝
	2	31	11¼	10	6¼	33	0⅝	10	10⅝	34	2⅜	11	3	35	4
				10	6⅜	33	1	10	10¾	34	2¾				
	2⅛	31	11⅝	10	6½	33	1⅜	10	10⅞	34	3⅛	11	3⅛	35	4½
	2¼	32	0	10	6⅝	33	1¾	10	11	34	3½	11	3¼	35	4⅞
	2⅜	32	0⅜	10	6¾	33	2⅛					11	3⅜	35	5¼
	2½	32	0¾	10	6⅞	33	2½	10	11⅛	34	3⅞	11	3½	35	5⅝
	2⅝	32	1⅛	10	7	33	2⅞	10	11¼	34	4¼	11	3⅝	35	6
	2¾	32	1½					10	11⅜	34	4⅝	11	3¾	35	6⅜
	2⅞	32	2	10	7⅛	33	3⅜	10	11½	34	5	11	3⅞	35	6¾
	3	32	2⅜	10	7¼	33	3¾	10	11⅝	34	5½	11	4	35	7¼
				10	7⅜	33	4⅛	10	11¾	34	5⅞				
0	3⅛	32	2¾	10	7½	33	4½	10	11⅞	34	6¼	11	4⅛	35	7⅝
0	3¼	32	3⅛	10	7⅝	33	4⅞	11	0	34	6⅝	11	4¼	35	8
0	3⅜	32	3½	10	7¾	33	5¼					11	4⅜	35	8⅜
0	3½	32	3⅞	10	7⅞	33	5⅝					11	4½	35	8¾
0	3⅝	32	4⅜	10	8	33	6⅛	11	0⅛	34	7	11	4⅝	35	9⅛
0	3¾	32	4¾					11	0¼	34	7⅜	11	4¾	35	9½
0	3⅞	32	5⅛	10	8⅛	33	6½	11	0⅜	34	7¾	11	4⅞	35	10
0	4	32	5½	10	8¼	33	6⅞	11	0½	34	8¼	11	5	35	10⅜
				10	8⅜	33	7¼	11	0⅝	34	8⅝				
10	4⅛	32	5⅞	10	8½	33	7⅝	11	0¾	34	9	11	5⅛	35	10¾
10	4¼	32	6¼	10	8⅝	33	8	11	0⅞	34	9⅜	11	5¼	35	11⅛
10	4⅜	32	6⅝	10	8¾	33	8⅜	11	1	34	9¾	11	5⅜	35	11½
10	4½	32	7	10	8⅞	33	8⅞					11	5½	35	11⅞
10	4⅝	32	7½	10	9	33	9¼	11	1⅛	34	10⅛	11	5⅝	36	0¼
10	4¾	32	7⅞					11	1¼	34	10½	11	5¾	36	0¾
10	4⅞	32	8¼	10	9⅛	33	9⅝	11	1⅜	34	11	11	5⅞	36	1⅛
10	5	32	8⅝	10	9¼	33	10	11	1½	34	11⅜	11	6	36	1½
				10	9⅜	33	10⅜	11	1⅝	34	11¾				
10	5⅛	32	9	10	9½	33	10¾	11	1¾	35	0⅛	11	6⅛	36	1⅞
10	5¼	32	9⅜	10	9⅝	33	11⅛	11	1⅞	35	0½	11	6¼	36	2¼
10	5⅜	32	9⅞	10	9¾	33	11½	11	2	35	0⅞	11	6⅜	36	2⅝

Diam.		Circum.	
Ft.	In.	Ft.	In.
11	6½	36	3
11	6⅝	36	3½
11	6¾	36	3⅞
11	6⅞	36	4¼
11	7	36	4⅝
11	7⅛	36	5
11	7¼	36	5⅜
11	7⅜	36	5⅞
11	7½	36	6¼
11	7⅝	36	6⅝
11	7¾	36	7
11	7⅞	36	7⅜
11	8	36	7¾
11	8⅛	36	8⅛
11	8¼	36	8½
11	8⅜	36	9
11	8½	36	9⅜
11	8⅝	36	9¾
11	8¾	36	10⅛
11	8⅞	36	10½
11	9	36	10⅞
11	9⅛	36	11¼
11	9¼	36	11¾
11	9⅜	37	0⅛
11	9½	37	0½
11	9⅝	37	0⅞
11	9¾	37	1¼
11	9⅞	37	1⅝
11	10	37	2
11	10⅛	37	2½
11	10¼	37	2⅞
11	10⅜	37	3¼
11	10½	37	3⅝
11	10⅝	37	4
11	10¾	37	4⅜

Diam.		Circum.	
Ft.	In.	Ft.	In.
11	10⅞	37	4⅞
11	11	37	5¼
11	11⅛	37	5⅝
11	11¼	37	6
11	11⅜	37	6⅜
11	11½	37	6¾
11	11⅝	37	7⅛
11	11¾	37	7½
11	11⅞	37	7⅞
12	0	37	8⅜
12	0⅛	37	8¾
12	0¼	37	9⅛
12	0⅜	37	9½
12	0½	37	9⅞
12	0⅝	37	10¼
12	0¾	37	10⅝
12	0⅞	37	11⅛
12	1	37	11½
12	1⅛	37	11⅞
12	1¼	38	0¼
12	1⅜	38	0⅝
12	1½	38	1
12	1⅝	38	1⅜
12	1¾	38	1⅞
12	1⅞	38	2¼
12	2	38	2⅝
12	2⅛	38	3
12	2¼	38	3⅜
12	2⅜	38	3¾
12	2½	38	4⅛
12	2⅝	38	4⅝
12	2¾	38	5
12	2⅞	38	5⅜
12	3	38	5¾

Diam.		Circum.	
Ft.	In.	Ft.	In.
12	3⅛	38	6⅛
12	3¼	38	6½
12	3⅜	38	6⅞
12	3½	38	7⅜
12	3⅝	38	7¾
12	3¾	38	8⅛
12	3⅞	38	8½
12	4	38	8⅞
12	4⅛	38	9¼
12	4¼	38	9⅝
12	4⅜	38	10⅛
12	4½	38	10½
12	4⅝	38	10⅞
12	4¾	38	11¼
12	4⅞	38	11⅝
12	5	39	0
12	5⅛	39	0⅜
12	5¼	39	0⅞
12	5⅜	39	1¼
12	5½	39	1⅝
12	5⅝	39	2
12	5¾	39	2⅜
12	5⅞	39	2¾
12	6	39	3⅛
12	6⅛	39	3⅝
12	6¼	39	4
12	6⅜	39	4⅜
12	6½	39	4¾
12	6⅝	39	5⅛
12	6¾	39	5½
12	6⅞	39	5⅞
12	7	39	6⅜
12	7⅛	39	6¾
12	7¼	39	7⅛
12	7⅜	39	7½

Diam.		Cir
Ft.	In.	Ft.
12	7½	39
12	7⅝	39
12	7¾	39
12	7⅞	39
12	8	39
12	8⅛	39
12	8¼	39
12	8⅜	39
12	8½	39
12	8⅝	39
12	8¾	39
12	8⅞	40
12	9	40
12	9⅛	40
12	9¼	40
12	9⅜	40
12	9½	40
12	9⅝	40
12	9¾	40
12	9⅞	40
12	10	40
12	10⅛	40
12	10¼	40
12	10⅜	40
12	10½	40
12	10⅝	40
12	10¾	40
12	10⅞	40
12	11	40
12	11⅛	40
12	11¼	40
12	11⅜	40
12	11½	40
12	11⅝	40
12	11¾	40

am.		Circum.	
	In.	Ft.	In.
	11⅞	40	9⅝
	0	40	10
	0⅛	40	10⅜
	0¼	40	10⅞
	0⅜	40	11¼
	0½	40	11⅝
	0⅝	41	0
	0¾	41	0⅜
	0⅞	41	0¾
	1	41	1⅛
	1⅛	41	1½
	1¼	41	2
	1⅜	41	2⅜
	1½	41	2¾
	1⅝	41	3⅛
	1¾	41	3½
	1⅞	41	3⅞
3	2	41	4¼
3	2⅛	41	4¾
3	2¼	41	5⅛
3	2⅜	41	5½
3	2½	41	5⅞
3	2⅝	41	6¼
3	2¾	41	6⅝
3	2⅞	41	7
3	3	41	7½
3	3⅛	41	7⅞
3	3¼	41	8¼
3	3⅜	41	8⅝
3	3½	41	9
3	3⅝	41	9⅜
3	3¾	41	9¾
3	3⅞	41	10¼
3	4	41	10⅝

Diam.		Circum.	
Ft.	In.	Ft.	In.
13	4⅛	41	11
13	4¼	41	11⅜
13	4⅜	41	11¾
13	4½	42	0⅛
13	4⅝	42	0½
13	4¾	42	1
13	4⅞	42	1⅜
13	5	42	1¾
13	5⅛	42	2⅛
13	5¼	42	2½
13	5⅜	42	2⅞
13	5½	42	3¼
13	5⅝	42	3¾
13	5¾	42	4⅛
13	5⅞	42	4½
13	6	42	4⅞
13	6⅛	42	5¼
13	6¼	42	5⅝
13	6⅜	42	6
13	6½	42	6½
13	6⅝	42	6⅞
13	6¾	42	7¼
13	6⅞	42	7⅝
13	7	42	8
13	7⅛	42	8⅜
13	7¼	42	8⅞
13	7⅜	42	9¼
13	7½	42	9⅝
13	7⅝	42	10
13	7¾	42	10⅜
13	7⅞	42	10¾
13	8	42	11⅛
13	8⅛	42	11½
13	8¼	43	0
13	8⅜	43	0⅜

Diam.		Circum.	
Ft.	In.	Ft.	In.
13	8½	43	0¾
13	8⅝	43	1⅛
13	8¾	43	1½
13	8⅞	43	1⅞
13	9	43	2¼
13	9⅛	43	2¾
13	9¼	43	3⅛
13	9⅜	43	3½
13	9½	43	3⅞
13	9⅝	43	4¼
13	9¾	43	4⅝
13	9⅞	43	5.
13	10	43	5½
13	10⅛	43	5⅞
13	10¼	43	6¼
13	10⅜	43	6⅝
13	10½	43	7
13	10⅝	43	7⅜
13	10¾	43	7¾
13	10⅞	43	8¼
13	11	43	8⅝
13	11⅛	43	9
13	11¼	43	9⅜
13	11⅜	43	9¾
13	11½	43	10⅛
13	11⅝	43	10½
13	11¾	43	11
13	11⅞	43	11⅜
14	0	43	11¾
14	0⅛	44	0⅛
14	0¼	44	0½
14	0⅜	44	0⅞
14	0½	44	1¼
14	0⅝	44	1¾
14	0¾	44	2⅛

Diam.		Circum.	
Ft.	In.	Ft.	In.
14	0⅞	44	2½
14	1	44	2⅞
14	1⅛	44	3¼
14	1¼	44	3⅝
14	1⅜	44	4
14	1½	44	4½
14	1⅝	44	4⅞
14	1¾	44	5¼
14	1⅞	44	5⅝
14	2	44	6
14	2⅛	44	6⅜
14	2¼	44	6⅞
14	2⅜	44	7¼
14	2½	44	7⅝
14	2⅝	44	8
14	2¾	44	8⅜
14	2⅞	44	8¾
14	3	44	9⅛
14	3⅛	44	9½
14	3¼	44	9⅞
14	3⅜	44	10⅜
14	3½	44	10¾
14	3⅝	44	11⅛
14	3¾	44	11½
14	3⅞	44	11⅞
14	4	45	0¼
14	4⅛	45	0⅝
14	4¼	45	1⅛
14	4⅜	45	1½
14	4½	45	1⅞
14	4⅝	45	2¼
14	4¾	45	2⅝
14	4⅞	45	3
14	5	45	3⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	5⅛	45	3⅞
14	5¼	45	4¼
14	5⅜	45	4⅝
14	5½	45	5
14	5⅝	45	5⅜
14	5¾	45	5¾
14	5⅞	45	6¼
14	6	45	6⅝
14	6⅛	45	7
14	6¼	45	7⅜
14	6⅜	45	7¾
14	6½	45	8⅛
14	6⅝	45	8½
14	6¾	45	9
14	6⅞	45	9⅜
14	7	45	9¾
14	7⅛	45	10⅛
14	7¼	45	10½
14	7⅜	45	10⅞
14	7½	45	11¼
14	7⅝	45	11⅝
14	7¾	46	0⅛
14	7⅞	46	0½
14	8	46	0⅞
14	8⅛	46	1¼
14	8¼	46	1⅝
14	8⅜	46	2
14	8½	46	2⅜
14	8⅝	46	2⅞
14	8¾	46	3¼
14	8⅞	46	3⅝
14	9	46	4
14	9⅛	46	4⅜
14	9¼	46	4¾
14	9⅜	46	5⅛
14	9½	46	5⅝
14	9⅝	46	6
14	9¾	46	6⅜
14	9⅞	46	6¾
14	10	46	7⅛
14	10⅛	46	7½
14	10¼	46	7⅞
14	10⅜	46	8⅜
14	10½	46	8¾
14	10⅝	46	9⅛
14	10¾	46	9½
14	10⅞	46	9⅞
14	11	46	10¼
14	11⅛	46	10⅝
14	11¼	46	11⅛
14	11⅜	46	11½
14	11½	46	11⅞
14	11⅝	47	0¼
14	11¾	47	0⅝
14	11⅞	47	1
15	0	47	1⅜
15	0⅛	47	1⅞
15	0¼	47	2¼
15	0⅜	47	2⅝
15	0½	47	3
15	0⅝	47	3⅜
15	0¾	47	3¾
15	0⅞	47	4⅛
15	1	47	4⅝
15	1⅛	47	5
15	1¼	47	5⅜
15	1⅜	47	5¾
15	1½	47	6⅛
15	1⅝	47	6½
15	1¾	47	6⅞
15	1⅞	47	7⅜
15	2	47	7¾
15	2⅛	47	8⅛
15	2¼	47	8½
15	2⅜	47	8⅞
15	2½	47	9¼
15	2⅝	47	9⅝
15	2¾	47	10⅛
15	2⅞	47	10½
15	3	47	10⅞
15	3⅛	47	11¼
15	3¼	47	11⅝
15	3⅜	48	0
15	3½	48	0⅜
15	3⅝	48	0⅞
15	3¾	48	1¼
15	3⅞	48	1⅝
15	4	48	2
15	4⅛	48	2⅜
15	4¼	48	2¾
15	4⅜	48	3⅛
15	4½	48	3½
15	4⅝	48	4
15	4¾	48	4⅜
15	4⅞	48	4¾
15	5	48	5⅛
15	5⅛	48	5½
15	5¼	48	5⅞
15	5⅜	48	6⅜
15	5½	48	6¾
15	5⅝	48	7⅛
15	5¾	48	7½
15	5⅞	48	7⅞
15	6	48	8¼
15	6⅛	48	8⅝
15	6¼	48	9
15	6⅜	48	9½
15	6½	48	9⅞
15	6⅝	48	10¼
15	6¾	48	10⅝
15	6⅞	48	11
15	7	48	11⅜
15	7⅛	48	11
15	7¼	49	0
15	7⅜	49	0
15	7½	49	1
15	7⅝	49	
15	7¾	49	
15	7⅞	49	
15	8	49	
15	8⅛	49	
15	8¼	49	
15	8⅜	49	
15	8½	49	
15	8⅝	49	
15	8¾	49	
15	8⅞	49	
15	9	49	
15	9⅛	49	
15	9¼	49	
15	9⅜	49	
15	9½	49	
15	9⅝	49	
15	9¾	49	
15	9⅞	49	
15	10	49	
15	10⅛	49	
15	10¼	49	
15	10⅜	49	

iam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
	9⅛	58	11¼	19	1⅛	59	11¾	19	5⅛	61	0⅜	19	9⅛	62	0⅞
	9¼	58	11⅝	19	1¼	60	0⅛	19	5¼	61	0¾	19	9¼	62	1¼
	9⅜	59	0	19	1⅜	60	0½	19	5⅜	61	1⅛	19	9⅜	62	1⅝
	9½	59	0⅜	19	1½	60	1	19	5½	61	1½	19	9½	62	2⅛
	9⅝	59	0¾	19	1⅝	60	1⅜	19	5⅝	61	1⅞	19	9⅝	62	2½
	9¾	59	1⅛	19	1¾	60	1¾	19	5¾	61	2¼	19	9¾	62	2⅞
	9⅞	59	1½	19	1⅞	60	2⅛	19	5⅞	61	2¾	19	9⅞	62	3¼
	10	59	2	19	2	60	2½	19	6	61	3⅛	19	10	62	3⅝
	10⅛	59	2⅜	19	2⅛	60	2⅞	19	6⅛	61	3½	19	10⅛	62	4
	10¼	59	2¾	19	2¼	60	3¼	19	6¼	61	3⅞	19	10¼	62	4⅜
	10⅜	59	3⅛	19	2⅜	60	3⅝	19	6⅜	61	4¼	19	10⅜	62	4⅞
	10½	59	3½	19	2½	60	4⅛	19	6½	61	4⅝	19	10½	62	5¼
	10⅝	59	3⅞	19	2⅝	60	4½	19	6⅝	61	5	19	10⅝	62	5⅝
	10¾	59	4¼	19	2¾	60	4⅞	19	6¾	61	5½	19	10¾	62	6
	10⅞	59	4¾	19	2⅞	60	5¼	19	6⅞	61	5⅞	19	10⅞	62	6⅜
	11	59	5⅛	19	3	60	5⅝	19	7	61	6¼	19	11	62	6¾
	11⅛	59	5½	19	3⅛	60	6	19	7⅛	61	6⅝	19	11⅛	62	7⅛
	11¼	59	5⅞	19	3¼	60	6½	19	7¼	61	7	19	11¼	62	7½
	11⅜	59	6¼	19	3⅜	60	6⅞	19	7⅜	61	7⅜	19	11⅜	62	8
	11½	59	6⅝	19	3½	60	7¼	19	7½	61	7¾	19	11½	62	8⅜
	11⅝	59	7	19	3⅝	60	7⅝	19	7⅝	61	8¼	19	11⅝	62	8¾
	11¾	59	7½	19	3¾	60	8	19	7¾	61	8⅝	19	11¾	62	9⅛
	11⅞	59	7⅞	19	3⅞	60	8⅜	19	7⅞	61	9	19	11⅞	62	9½
	0	59	8¼	19	4	60	8¾	19	8	61	9⅜	20	0	62	9⅞
	0⅛	59	8⅝	19	4⅛	60	9¼	19	8⅛	61	9¾	20	0⅛	62	10⅜
	0¼	59	9	19	4¼	60	9⅝	19	8¼	61	10⅛	20	0¼	62	10¾
	0⅜	59	9⅜	19	4⅜	60	10	19	8⅜	61	10½	20	0⅜	62	11⅛
	0½	59	9¾	19	4½	60	10⅜	19	8½	61	11	20	0½	62	11½
9	0⅝	59	10¼	19	4⅝	60	10¾	19	8⅝	61	11⅜	20	0⅝	62	11⅞
9	0¾	59	10⅝	19	4¾	60	11⅛	19	8¾	61	11¾	20	0¾	63	0¼
9	0⅞	59	11	19	4⅞	60	11½	19	8⅞	62	0⅛	20	0⅞	63	0⅝
9	1	59	11⅜	19	5	60	11⅞	19	9	62	0½				

OBSERVATIONS ON TABLE I.

I do not intend to enter into any laboured argument to prove the general utility of these Tables, as their simplicity and clearness are sufficient to stamp their value to the artist and mechanic. It will be clearly perceived, on inspection, that the Table commences with as small a diameter as is generally used in hoops and rings, viz. one inch, and increases by the regular gradation of one-eighth of an inch, to upwards of twenty feet; and in the column marked Circumference, against each Diameter stand the respective circumferences: hence all that is necessary on inspecting these Tables is to enter into them with any proposed diameter or circumference, and an answer to the inquiry is immediately obtained.

Example.—Required the circumference of a circle the diameter being 11 feet 7⅞ inches.

In the column of circumferences, opposite the given diameter, stands 36 feet 7⅜ inches, the circumference required.

But it will be necessary to observe, that in the formation of hoops and rings a contraction of the metal takes place. Now, the just allowance for this contraction is the exact thickness of the metal, which must be added to the diameter.

Ex. In making a hoop whose diameter inside is 6 feet 9⅛ inches, the thickness of the iron being ½ inch, this ½ inch must be added to the given diameter, which will make it 6 feet 9⅝ inches; this will allow 1⅝ inch for the contraction in bending in a hoop of the above diameter, giving the circum*ference* or length of iron required for the hoop, 21 *feet 4⅜ inches.*

The foregoing example appertains to the formation of hoops or iron bent on the flat; but in the formation of rings or iron bent on the edge, the same rule must also be followed, only taking care to add the *breadth* instead of the thickness. As for example:

To make a ring whose inside diameter is 8 feet 2¼ inches, the *breadth* of the iron being 2½ inches; by adding the 2½ inches to the given diameter, will increase it to 8 feet 4¾ inches; opposite to this diameter in the column of circumferences stands 26 feet 4½ inches, being the length of iron necessary for the ring.

The foregoing observations relate more particularly to plain hoops and rings; but as respects the hoops that are on the wheels of railway carriages, a difference must be observed, which is as follows: These hoops having a flange projecting on the one edge of the surface it will be necessary, in addition to the thickness of the metal, to add two-thirds of the thickness of the flange to the diameter, as the flange side would contract considerably more than the plain surface; this is supposing the tires are in a straight form, but, in general, they come from the iron-works in a curved state, as represented in the engraving, figure 3. In the latter case, it will be only necessary to add the thickness of the bare metal, as the aforesaid portion of the thickness of the flange is allowed for in the curve. By having had some experience in hoops of this nature, I have found that the curve may be exactly obtained, by using four times the circumference of the hoop as a radius.

In the engraving, fig. 1, is given a representation of a tire in its curved state, fixed to the blocks, and in the act of being bent; but if the tire has not been *previously curved,* it may easily be done in the operation of bending: the smith must pay particular attention to this, or he will have his hoop bent in an angle.

Figures 1 and 2.

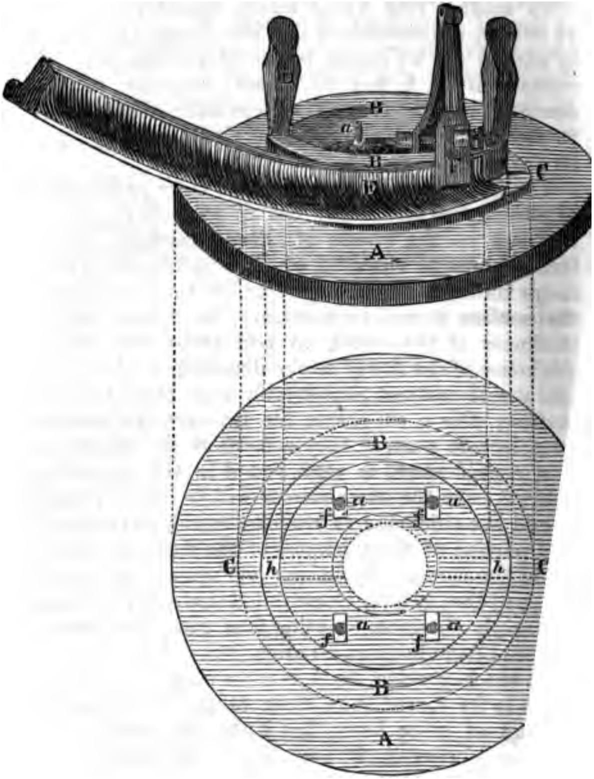
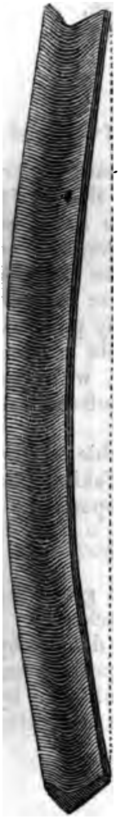


Figure 3.



The following is a description of the figures 1 and 2: A is a strong cast-iron ground-plate, in which *f f f f* are four slot-holes for the bolts *a a a a* to slide in, and are for the purpose of screwing down the two semicircular blocks, to prevent them from moving whilst the tire is in the act of being bent. B B is the block in two halves, opening at C C; the aperture is cut in a conical form, for the reception of the two conical wedges D D, on which the tire E is represented. *h h* are two holes in the ground-plate, into which the wedges are driven whilst blocking the hoop. F is a strong cramp for screwing the tire firm to the block whilst in the act of being bent round it: it is made with a joint at the top, and secures the tire to the block by means of a strong square-threaded screw, which screws into a boss on the innermost leg.

But the practical utility of this Table is not confined to smiths alone; to the millwright it will be found equally useful and expeditious, as on a bare inspection of the Table he may ascertain the diameter of any wheel that may be required to be made, the pitch and number of teeth being given.

Ex. Suppose a wheel were ordered to be made to contain sixty teeth, the pitch of the teeth to be 3⅞ inches, the dimensions of the wheel may be ascertained simply as follows:

Multiply the pitch of the tooth by the

number of teeth the wheel is to contain, and the product will be the circumference of the wheel: thus

Inches.
$3\frac{7}{8}$ the pitch of the tooth,
$10 \times 6 = 60$, the number of teeth,

---

3 $2\frac{3}{4}$
6

Feet 19 $4\frac{1}{2}$ the circumference of the wheel.

However, by inspecting the column marked Circumference, I find the nearest number to this is 19 feet $4\frac{3}{8}$ inches, which is the eighth of an inch less than the true circumference; but if this $\frac{1}{8}$ were divided into sixty equal parts, it would not make the difference of a single hair's-breadth in the size of each tooth; so that it is sufficiently near for any practical purpose. The diameter answering to this circumference is 6 feet 2 inches; consequently, with one half of this number as a radius, the circumference of the wheel will be described.

The manner in which the foregoing Table of Circumferences is found is as follows: Taking the diameter at unity, we have by decimal proportion

$$\text{As } 1 : 3{\cdot}1416 :: \overset{\text{In.}}{1{\cdot}} : \overset{\text{In.}}{3{\cdot}1416},$$

and the decimal 1416 multiplied by 8, gives the circumference for 1 inch of diameter $3\frac{1}{8}$ inches.

In these Tables the number 3·1416 is divided by 8, which gives ·3927. This decimal proportion has been used as a constant, and the sum multiplied by 8 gives the excess above the decimal value in eighths of an inch.

EXAMPLE.

Diam.		In.	Circum.
1	....	3	1416 × 8 = ⅛·1328 + ·3927
1⅛	....	3	·5343 × 8 = ½·2744 + ·3927
1¼	....	3	·9270 × 8 = ⅞·7160 + ·3927
1⅜	....	4	·3197 × 8 = ¼·6576 + ·3927
1½	....	4	·7124 × 8 = ⅝·6922 + ·3927
1⅝	....	5	·1051 × 8 = ·8408 + ·3927
1¾	....	5	·4978 × 8 = ⅜·9824 + ·3927
1⅞	....	5	·8905 × 8 = ⅞·1240 + ·3927
2	....	6	·2832 × 8 = ¼·2656

ote.—The nearest eighth of an inch is only given, as I ght it quite unnecessary to add the first decimal figure is Table.

J. F.

TABLE II.*

OWING THE WEIGHT OF A LINEAL FOOT OF MALLEABLE RECTANGULAR OR FLAT IRON,

rom an Eighth of an Inch to Three Inches thick; advancing by an Eighth and Quarter of an Inch in breadth.

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅛	¼	0	1·6	⅛	3⅞	1	9·7	⅛	7½	3	1·8
	⅜	0	2·4		4	1	10·5		7⅝	3	2·6
	½	0	3·3		4⅛	1	11·3		7¾	3	3·4
	⅝	0	4·1		4¼	1	12·2		7⅞	3	4·3
	¾	0	5·0		4⅜	1	13·0		8	3	5·1
	⅞	0	5·8		4½	1	13·8		8⅛	3	5·9
	1	0	6·6		4⅝	1	14·7		8¼	3	6·7
	1⅛	0	7·5		4¾	1	15·5		8⅜	3	7·6
	1¼	0	8·3		4⅞	2	0·3		8½	3	8·4
	1⅜	0	9·1		5	2	1·2		8⅝	3	9·2
	1½	0	9·9		5⅛	2	2·0		8¾	3	10·1
	1⅝	0	10·8		5¼	2	2·8		8⅞	3	11·0
	1¾	0	11·6		5⅜	2	3·7		9	3	11·7
	1⅞	0	12·4		5½	2	4·5		9⅛	3	12·6
	2	0	13·2		5⅝	2	5·3		9¼	3	13·4
	2⅛	0	14·1		5¾	2	6·1		9⅜	3	14·2
	2¼	0	14·9		5⅞	2	7·0		9½	3	15·0
	2⅜	0	15·7		6	2	7·8		9⅝	3	15·9
	2½	1	0·6		6⅛	2	8·6		9¾	4	0·7
	2⅝	1	1·4		6¼	2	9·5		9⅞	4	1·5
	2¾	1	2·2		6⅜	2	10·3		10	4	2·4
	2⅞	1	3·0		6½	2	11·1		10⅛	4	3·2
	3	1	3·9		6⅝	2	12·0		10¼	4	4·0
	3⅛	1	4·7		6¾	2	12·8		10⅜	4	4·9
	3¼	1	5·5		6⅞	2	13·6		10½	4	5·
	3⅜	1	6·4		7	2	14·4		10⅝	4	6·
	3½	1	7·2		7⅛	2	15·3		10¾	4	7·
	3⅝	1	8·0		7¼	3	0·1		10⅞	4	8
	3¾	1	8·9		7⅜	3	1·0		11	4	[illegible]

---

* James Foden.

Thick.	Broad.	lbs.	oz.
in.	in.		
⅛	11⅛	4	9·8
	11¼	4	10·7
	11⅜	4	11·5
	11½	4	12·3
	11⅝	4	13·2
	11¾	4	14·0
	11⅞	4	14·8
	12	4	15·6
¼	½	0	6·6
	⅝	0	8·3
	¾	0	10·0
	⅞	0	11·6
	1	0	13·2
	1⅛	0	14·9
	1¼	1	0·6
	1⅜	1	2·2
	1½	1	3·9
	1⅝	1	5·5
	1¾	1	7·2
	1⅞	1	9·0
	2	1	10·5
	2⅛	1	12·2
	2¼	1	13·8
	2⅜	1	15·5
	2½	2	1·2
	2⅝	2	2·8
	2¾	2	4·5
	2⅞	2	6·1
	3	2	7·8
	3⅛	2	9·5
	3¼	2	11·1
	3⅜	2	12·8
	3½	2	14·4
	3⅝	3	0·1
	3¾	3	1·8
	3⅞	3	3·4
in.	in.		
¼	4	3	5·1
	4⅛	3	6·7
	4¼	3	8·4
	4⅜	3	10·1
	4½	3	11·7
	4⅝	3	13·4
	4¾	3	15·0
	4⅞	4	0·7
	5	4	2·4
	5⅛	4	4·0
	5¼	4	5·7
	5⅜	4	7·3
	5½	4	9·0
	5⅝	4	10·7
	5¾	4	12·3
	5⅞	4	14·0
	6	4	15·6
	6⅛	5	1·3
	6¼	5	3·0
	6⅜	5	4·6
	6½	5	6·3
	6⅝	5	7·9
	6¾	5	9·6
	6⅞	5	11·3
	7	5	13·0
	7⅛	5	14·6
	7¼	6	0·2
	7⅜	6	2·0
	7½	6	3·6
	7⅝	6	5·2
	7¾	6	7·0
	7⅞	6	8·5
	8	6	10·2
	8⅛	6	12·0
	8¼	6	13·5
	8⅜	6	15·2
	8½	7	0·8
in.	in.		
¼	8⅝	7	2·5
	8¾	7	4·2
	8⅞	7	5·8
	9	7	7·5
	9⅛	7	9·1
	9¼	7	10·8
	9⅜	7	12·5
	9½	7	14·1
	9⅝	7	15·8
	9¾	8	1·4
	9⅞	8	3·1
	10	8	4·8
	10⅛	8	6·4
	10¼	8	8·1
	10⅜	8	9·7
	10½	8	11·4
	10⅝	8	13·1
	10¾	8	14·7
	10⅞	9	0·4
	11	9	2·0
	11⅛	9	3·7
	11¼	9	5·4
	11⅜	9	7·0
	11½	9	8·7
	11⅝	9	10·3
	11¾	9	12·0
	11⅞	9	13·7
	12	9	15·3
⅜	¾	0	14·9
	⅞	1	1·3
	1	1	3·8
	1⅛	1	6·3
	1¼	1	8·8
	1⅜	1	11·3
	1½	1	13·8
	1⅝	2	0·3

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅜	1¾	2	2·7	⅜	6⅜	7	14·6	⅜	11	13	10·5
	1⅞	2	5·2		6½	8	1·1		11⅛	13	13·0
	2	2	7·7		6⅝	8	3·6		11¼	13	15·5
	2⅛	2	10·2		6¾	8	6·1		11⅜	14	2·0
	2¼	2	12·7		6⅞	8	8·6		11½	14	4·5
	2⅜	2	15·1		7	8	11·1		11⅝	14	7·0
	2½	3	1·6		7⅛	8	13·5		11¾	14	9·4
	2⅝	3	4·1		7¼	9	0·0		11⅞	14	11·9
	2¾	3	6·6		7⅜	9	2·5		12	14	14·4
	2⅞	3	9·1		7½	9	5·0				
	3	3	11·6		7⅝	9	7·5	½	1	1	10·4
	3⅛	3	14·1		7¾	9	10·0		1⅛	1	13·8
	3¼	4	0·5		7⅞	9	12·4		1¼	2	1·1
	3⅜	4	3·0		8	9	14·9		1⅜	2	4·4
	3½	4	5·5		8⅛	10	1·4		1½	2	7·7
	3⅝	4	8·0		8¼	10	3·9		1⅝	2	11·0
	3¾	4	10·5		8⅜	10	6·4		1¾	2	14·3
	3⅞	4	13·0		8½	10	8·9		1⅞	3	1·6
	4	4	15·4		8⅝	10	11·3		2	3	4·9
	4⅛	5	1·9		8¾	10	13·8		2⅛	3	8·3
	4¼	5	4·4		8⅞	11	0·3		2¼	3	11·6
	4⅜	5	6·9		9	11	2·8		2⅜	3	14·9
	4½	5	9·4		9⅛	11	5·3		2½	4	2·2
	4⅝	5	11·9		9¼	11	7·8		2⅝	4	5·5
	4¾	5	14·3		9⅜	11	10·3		2¾	4	8·
	4⅞	6	0·8		9½	11	12·7		2⅞	4	12·
	5	6	3·3		9⅝	11	15·2		3	4	15·
	5⅛	6	5·8		9¾	12	1·7		3⅛	5	2·
	5¼	6	8·3		9⅞	12	4·2		3¼	5	6·
	5⅜	6	10·8		10	12	6·7		3⅜	5	9
	5½	6	13·2		10⅛	12	9·2		3½	5	12
	5⅝	6	15·7		10¼	12	11·6		3⅝	6	
	5¾	7	2·2		10⅜	12	14·1		3¾	6	
	5⅞	7	4·7		10½	13	0·6		3⅞	6	
	6	7	7·2		10⅝	13	3·1		4	6	
	6⅛	7	9·7		10¾	13	5·6		4⅛	6	1
	6¼	7	12·2		10⅞	13	8·1		4¼	7	

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
½	4⅜	7	3·9	½	9	14	14·4	⅝	2⅝	5	6·9
	4½	7	7·2		9⅛	15	1·7		2¾	5	11·0
	4⅝	7	10·5		9¼	15	5·0		2⅞	5	15·2
	4¾	7	13·8		9⅜	15	8·4		3	6	3·3
	4⅞	8	1·1		9½	15	11·7		3⅛	6	7·5
	5	8	4·4		9⅝	15	15·0		3¼	6	11·6
	5⅛	8	7·7		9¾	16	2·3		3⅜	6	15·7
	5¼	8	11·1		9⅞	16	5·6		3½	7	3·9
	5⅜	8	14·4		10	16	8·9		3⅝	7	8·0
	5½	9	1·7		10⅛	16	12·2		3¾	7	12·2
	5⅝	9	5·0		10¼	16	15·5		3⅞	8	0·3
	5¾	9	8·3		10⅜	17	2·8		4	8	4·4
	5⅞	9	11·6		10½	17	6·2		4⅛	8	8·6
	6	9	14·9		10⅝	17	9·5		4¼	8	12·7
	6⅛	10	2·2		10¾	17	12·8		4⅜	9	0·9
	6¼	10	5·6		10⅞	18	0·1		4½	9	5·0
	6⅜	10	8·9		11	18	3·4		4⅝	9	9·1
	6½	10	12·2		11⅛	18	6·7		4¾	9	13·3
	6⅝	10	15·5		11¼	18	10·0		4⅞	10	1·4
	6¾	11	2·8		11⅜	18	13·3		5	10	5·6
	6⅞	11	6·1		11½	19	0·7		5⅛	10	9·7
	7	11	9·4		11⅝	19	4·0		5¼	10	13·8
	7⅛	11	12·7		11¾	19	7·3		5⅜	11	2·0
	7¼	12	0·0		11⅞	19	10·6		5½	11	6·1
	7⅜	12	3·4		12	19	13·9		5⅝	11	10·3
	7½	12	6·7						5¾	11	14·4
	7⅝	12	10·0	⅝	1¼	2	9·4		5⅞	12	2·5
	7¾	12	13·3		1⅜	2	13·5		6	12	6·7
	7⅞	13	0·6		1½	3	1·6		6⅛	12	10·8
	8	13	3·9		1⅝	3	5·8		6¼	12	15·0
	8⅛	13	7·2		1¾	3	9·9		6⅜	13	3·1
	8¼	13	10·5		1⅞	3	14·1		6½	13	7·2
	8⅜	13	13·9		2	4	2·2		6⅝	13	11·4
	8½	14	1·2		2⅛	4	6·3		6¾	13	15·5
	8⅝	14	4·5		2¼	4	10·5		6⅞	14	3·7
	8¾	14	7·8		2⅜	4	14·6		7	14	7·8
	8⅞	14	11·1		2½	5	2·8		7⅛	14	11·9

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅝	7¼	15	0·1	⅝	11⅞	24	9·3	¾	5¾	14	4·5
	7⅜	15	4·2		12	24	13·4		5⅞	14	9·5
	7½	15	8·4						6	14	14·4
	7⅝	15	12·5	¾	1½	3	11·6		6⅛	15	3·4
	7¾	16	0·6		1⅝	4	0·5		6¼	15	8·4
	7⅞	16	4·8		1¾	4	5·5		6⅜	15	13·3
	8	16	8·9		1⅞	4	10·5		6½	16	2·3
	8⅛	16	13·1		2	4	15·4		6⅝	16	7·3
	8¼	17	1·2		2⅛	5	4·4		6¾	16	12·2
	8⅜	17	5·3		2¼	5	9·4		6⅞	17	1·2
	8½	17	9·5		2⅜	5	14·3		7	17	6·2
	8⅝	17	13·6		2½	6	3·3		7⅛	17	11·1
	8¾	18	1·8		2⅝	6	8·3		7¼	18	0·1
	8⅞	18	5·9		2¾	6	13·2		7⅜	18	5·1
	9	18	10·0		2⅞	7	2·2		7½	18	10·0
	9⅛	18	14·2		3	7	7·2		7⅝	18	15·0
	9¼	19	2·3		3⅛	7	12·2		7¾	19	4·0
	9⅜	19	6·5		3¼	8	1·1		7⅞	19	8·9
	9½	19	10·6		3⅜	8	6·1		8	19	13·9
	9⅝	19	14·7		3½	8	11·1		8⅛	20	2·9
	9¾	20	2·9		3⅝	9	0·0		8¼	20	7·8
	9⅞	20	7·0		3¾	9	5·0		8⅜	20	12·8
	10	20	11·2		3⅞	9	10·0		8½	21	1·8
	10⅛	20	15·3		4	9	14·9		8⅝	21	6·7
	10¼	21	3·4		4⅛	10	3·9		8¾	21	11·7
	10⅜	21	7·6		4¼	10	8·9		8⅞	22	0·7
	10½	21	11·7		4⅜	10	13·8		9	22	5·7
	10⅝	21	15·9		4½	11	2·8		9⅛	22	10·6
	10¾	22	4·0		4⅝	11	7·8		9¼	22	15·6
	10⅞	22	8·1		4¾	11	12·7		9⅜	23	4·6
	11	22	12·3		4⅞	12	1·7		9½	23	9·5
	11⅛	23	0·4		5	12	6·7		9⅝	23	14·5
	11¼	23	4·6		5⅛	12	11·6		9¾	24	3·5
	11⅜	23	8·7		5¼	13	0·6		9⅞	24	8·4
	11½	23	12·8		5⅜	13	5·6		10	24	13·4
	11⅝	24	1·0		5½	13	10·6		10⅛	25	2·
	11¾	24	5·1		5⅝	13	15·5		10¼	25	7·

Broad.	qrs.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.				in.	in.			in.	in.			
10⅜	0	25	12·3	⅞	4½	13	0·6	⅞	9⅛	0	26	7·1
10½	0	26	1·3		4⅝	13	6·4		9¼	0	26	12·9
10⅝	0	26	6·2		4¾	13	12·2		9⅜	0	27	2·7
10¾	0	26	11·2		4⅞	14	2·0		9½	0	27	8·5
10⅞	0	27	0·2		5	14	7·8		9⅝	0	27	14·3
11	0	27	5·1		5⅛	14	13·6		9¾	1	0	4·0
11⅛	0	27	10·1		5¼	15	3·4		9⅞	1	0	9·8
11¼	0	27	15·1		5⅜	15	9·2		10	1	0	15·6
11⅜	1	0	4·0		5½	15	15·0		10⅛	1	1	5·4
11½	1	0	9·0		5⅝	16	4·8		10¼	1	1	11·2
11⅝	1	0	14·0		5¾	16	10·6		10⅜	1	2	1·0
11¾	1	1	3·0		5⅞	17	0·4		10½	1	2	6·8
11⅞	1	1	7·9		6	17	6·2		10⅝	1	2	12·6
12	1	1	12·9		6⅛	17	12·0		10¾	1	3	2·4
					6¼	18	1·8		10⅞	1	3	8·2
1¾	0	5	1·1		6⅜	18	7·6		11	1	3	14·0
1⅞	0	5	6·9		6½	18	13·4		11⅛	1	4	3·8
2	0	5	12·7		6⅝	19	3·1		11¼	1	4	9·6
2⅛	0	6	2·5		6¾	19	8·9		11⅜	1	4	15·4
2¼	0	6	8·3		6⅞	19	14·7		11½	1	5	5·2
2⅜	0	6	14·1		7	20	4·5		11⅝	1	5	11·0
2½	0	7	3·9		7⅛	20	10·3		11¾	1	6	0·8
2⅝	0	7	9·7		7¼	21	0·1		11⅞	1	6	6·6
2¾	0	7	15·5		7⅜	21	5·9		12	1	6	12·4
2⅞	0	8	5·3		7½	21	11·7					
3	0	8	11·1		7⅝	22	1·5	1	2	0	6	10·0
3⅛	0	9	0·9		7¾	22	7·3		2⅛	0	7	0·6
3¼	0	9	6·7		7⅞	22	13·1		2¼	0	7	7·2
3⅜	0	9	12·4		8	23	2·9		2⅜	0	7	13·8
3½	0	10	2·2		8⅛	23	8·7		2½	0	8	4·4
3⅝	0	10	8·0		8¼	23	14·5		2⅝	0	8	11·1
3¾	0	10	13·8		8⅜	24	4·3		2¾	0	9	1·7
3⅞	0	11	3·6		8½	24	10·1		2⅞	0	9	8·3
4	0	11	9·4		8⅝	24	15·9		3	0	9	14·7
4⅛	0	11	15·2		8¾	25	5·7		3⅛	0	10	5·6
4¼	0	12	5·0		8⅞	25	11·5		3¼	0	10	12·2
4⅜	0	12	10·8		9	26	1·3		3⅜	0	11	2·8

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			in.	in.				in.	in.			
1	3½	11	9·4	1	6⅜	0	21	1·8	1	9¼	1	2	10·1
	3⅝	12	0·1		6½	0	21	8·4		9⅜	1	3	0·8
	3¾	12	6·7		6⅝	0	21	15·0		9½	1	3	7·4
	3⅞	12	13·3		6¾	0	22	5·7		9⅝	1	3	14·0
	4	13	3·9		6⅞	0	22	12·3		9¾	1	4	4·6
	4⅛	13	10·6		7	0	23	2·9		9⅞	1	4	11·2
	4¼	14	1·2		7⅛	0	23	9·5		10	1	5	1·9
	4⅜	14	7·8		7¼	0	24	0·2		10⅛	1	5	8·5
	4½	14	14·4		7⅜	0	24	6·6		10¼	1	5	15·1
	4⅝	15	5·0		7½	0	24	13·4		10⅜	1	6	5·8
	4¾	15	11·7		7⅝	0	25	4·0		10½	1	6	12·4
	4⅞	16	2·3		7¾	0	25	10·6		10⅝	1	7	3·0
	5	16	8·9		7⅞	0	26	1·3		10¾	1	7	9·6
	5⅛	16	15·5		8	0	26	7·9		10⅞	1	8	0·2
	5¼	17	6·2		8⅛	0	26	14·5		11	1	8	6·9
	5⅜	17	12·8		8¼	0	27	5·1		11⅛	1	8	13·5
	5½	18	3·4		8⅜	0	27	11·8		11¼	1	9	4·1
	5⅝	18	10·0		8½	1	0	2·4		11⅜	1	9	10·7
	5¾	19	0·7		8⅝	1	0	9·0		11½	1	10	1·4
	5⅞	19	7·3		8¾	1	0	15·6		11⅝	1	10	8·0
	6	19	13·9		8⅞	1	1	6·3		11¾	1	10	14·
	6⅛	20	4·5		9	1	1	12·9		11⅞	1	11	5·
	6¼	20	11·2		9⅛	1	2	3·5		12	1	11	11·

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.				in.	in.				in.	in.			
1⅛	2¼	0	8	6·1	1⅛	11½	1	14	13·5	1¼	10¾	1	16	8·0
	2½	0	9	5·0		11¾	1	15	12·4		11	1	17	8·6
	2¾	0	10	3·9		12	1	16	11·4		11¼	1	18	9·2
	3	0	11	2·8							11½	1	19	9·7
	3¼	0	12	1·7	1¼	2½	0	10	5·6		11¾	1	20	10·3
	3½	0	13	0·6		2¾	0	11	6·1		12	1	21	10·8
	3¾	0	13	15·5		3	0	12	6·7					
	4	0	14	14·4		3¼	0	13	7·2	1⅜	2¾	0	12	8·3
	4¼	0	15	13·3		3½	0	14	7·8		3	0	13	10·6
	4½	0	16	12·2		3¾	0	15	8·4		3¼	0	14	12·8
	4¾	0	17	11·1		4	0	16	8·9		3½	0	15	15·0
	5	0	18	10·0		4¼	0	17	9·5		3¾	0	17	1·2
	5¼	0	19	8·9		4½	0	18	10·0		4	0	18	3·4
	5½	0	20	7·8		4¾	0	19	10·6		4¼	0	19	5·6
	5¾	0	21	6·8		5	0	20	11·2		4½	0	20	7·8
	6	0	22	5·7		5¼	0	21	11·7		4¾	0	21	10·1
	6¼	0	23	4·6		5½	0	22	12·3		5	0	22	12·3
	6½	0	24	3·5		5¾	0	23	12·8		5¼	0	23	14·5
	6¾	0	25	2·4		6	0	24	13·4		5½	0	25	0·7
	7	0	26	1·3		6¼	0	25	14·0		5¾	0	26	2·9
	7¼	0	27	0·2		6½	0	26	14·5		6	0	27	5·1
	7½	0	27	15·1		6¾	0	27	15·1		6¼	1	0	7·4
	7¾	1	0	14·0		7	1	0	15·6		6½	1	1	9·6
	8	1	1	12·9		7¼	1	2	0·2		6¾	1	2	11·8
	8¼	1	2	11·8		7½	1	3	0·8		7	1	3	14·0
	8½	1	3	10·7		7¾	1	4	1·3		7¼	1	5	0·2
	8¾	1	4	9·6		8	1	5	1·9		7½	1	6	2·4
	9	1	5	8·5		8¼	1	6	2·4		7¾	1	7	4·7
	9¼	1	6	7·4		8½	1	7	3·0		8	1	8	6·9
	9½	1	7	6·3		8¾	1	8	3·6		8¼	1	9	9·1
	9¾	1	8	5·2		9	1	9	4·1		8½	1	10	11·3
	10	1	9	4·1		9¼	1	10	4·7		8¾	1	11	13·5
	10¼	1	10	3·0		9½	1	11	5·2		9	1	12	15·7
	10½	1	11	1·9		9¾	1	12	5·8		9¼	1	14	2·0
	10¾	1	12	0·8		10	1	13	6·4		9½	1	15	4·2
	11	1	12	15·7		10¼	1	14	6·9		9¾	1	16	6·4
	11¼	1	13	14·6		10½	1	15	7·5		10	1	17	8·6

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.
in.	in.				in.	in.				in.	in.	
1⅜	10¼	1	18	10·8	1½	10	1	21	10·8	1⅝	10	1
	10½	1	19	13·0		10¼	1	22	14·7		10¼	1
	10¾	1	20	15·2		10½	1	24	2·6		10½	2
	11	1	22	1·5		10¾	1	25	6·5		10¾	2
	11¼	1	23	3·7		11	1	26	10·3		11	2
	11½	1	24	5·9		11¼	1	27	14·2		11¼	2
	11¾	1	25	8·1		11½	2	1	2·1		11½	2
	12	1	26	10·3		11¾	2	2	5·9		11¾	2
						12	2	3	9·8		12	2
1½	3	0	14	14·4								
	3¼	0	16	2·3	1⅝	3¼	0	17	7·8	1¾	3½	0
	3½	0	17	6·2		3½	0	18	13·4		3¾	0
	3¾	0	18	10·0		3¾	0	20	2·9		4	0
	4	0	19	13·9		4	0	21	8·4		4¼	0
	4¼	0	21	1·8		4¼	0	22	13·9		4½	0
	4½	0	22	5·7		4½	0	24	3·5		4¾	0
	4¾	0	23	9·5		4¾	0	25	9·0		5	1
	5	0	24	13·4		5	0	26	14·5		5¼	1
	5¼	0	26	1·3		5¼	1	0	4·0		5½	1
	5½	0	27	5·1		5½	1	1	9·6		5¾	1
	5¾	1	0	9·0		5¾	1	2	15·1		6	1
	6	1	1	12·9		6	1	4	4·6		6¼	1
	6¼	1	3	0·8		6¼	1	5	10·2		6½	1
	6½	1	4	4·6		6½	1	6	15·7		6¾	1
	6¾	1	5	8·5		6¾	1	8	5·2		7	1
	7	1	6	12·4		7	1	9	10·7		7¼	1
	7¼	1	8	0·2		7¼	1	11	0·3		7½	1
	7½	1	9	4·1		7½	1	12	5·8		7¾	1
	7¾	1	10	8·0		7¾	1	13	11·3		8	1
	8	1	11	11·9		8	1	15	0·9		8¼	1
	8¼	1	12	15·7		8¼	1	16	6·4		8½	1
	8½	1	14	3·6		8½	1	17	11·9		8¾	1
	8¾	1	15	7·5		8¾	1	19	1·4		9	1
	9	1	16	11·4		9	1	20	7·0		9¼	1
	9¼	1	17	15·2		9¼	1	21	12·5		9½	1
	9½	1	19	3·1		9½	1	23	2·0		9¾	2
	9¾	1	20	7·0		9¾	1	24	7·6		10	2

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1¾	10¼	2	3	6·5
	10½	2	4	13·7
	10¾	2	6	4·9
	11	2	7	12·1
	11¼	2	9	3·2
	11½	2	10	10·4
	11¾	2	12	1·6
	12	2	13	8·8
1⅞	3¾	0	23	4·6
	4	0	24	13·4
	4¼	0	26	6·2
	4½	0	27	15·1
	4¾	1	1	7·9
	5	1	3	0·8
	5¼	1	4	9·6
	5½	1	6	2·4
	5¾	1	7	11·3
	6	1	9	4·6
	6¼	1	10	13·0
	6½	1	12	5·8
	6¾	1	13	14·6
	7	1	15	7·5
	7¼	1	17	0·3
	7½	1	18	9·2
	7¾	1	20	2·0
	8	1	21	10·8
	8¼	1	23	3·7
	8½	1	24	12·5
	8¾	1	26	5·4
	9	1	27	14·2
	9¼	2	1	7·0
	9½	2	2	15·9
	9¾	2	4	8·7
	10	2	6	1·6
	10¼	2	7	10·4
	10½	2	9	3·2
in.	in.			
1⅞	10¾	2	10	12·1
	11	2	12	4·9
	11¼	2	13	13·8
	11½	2	15	6·6
	11¾	2	16	15·4
	12	2	18	8·3
2	4	0	26	7·9
	4¼	1	0	2·4
	4½	1	1	12·9
	4¾	1	3	7·4
	5	1	5	1·9
	5¼	1	6	12·4
	5½	1	8	6·9
	5¾	1	10	1·4
	6	1	11	11·9
	6¼	1	13	6·4
	6½	1	15	0·9
	6¾	1	16	11·4
	7	1	18	5·8
	7¼	1	20	0·3
	7½	1	21	10·8
	7¾	1	23	5·3
	8	1	24	15·8
	8¼	1	26	10·3
	8½	2	0	4·8
	8¾	2	1	15·3
	9	2	3	9·0
	9¼	2	5	4·3
	9½	2	6	14·8
	9¾	2	8	9·3
	10	2	10	3·8
	10¼	2	11	14·3
	10½	2	13	8·8
	10¾	2	15	3·3
	11	2	16	13·8
	11¼	2	18	8·3
in.	in.			
2	11½	2	20	2·8
	11¾	2	21	13·3
	12	2	23	7·8
2⅛	4¼	1	1	14·5
	4½	1	3	10·7
	4¾	1	5	6·8
	5	1	7	3·0
	5¼	1	8	15·2
	5½	1	10	11·3
	5¾	1	12	7·5
	6	1	14	3·6
	6¼	1	15	15·8
	6½	1	17	11·9
	6¾	1	19	8·1
	7	1	21	4·2
	7¼	1	23	0·4
	7½	1	24	12·5
	7¾	1	26	8·7
	8	2	0	4·8
	8¼	2	2	1·0
	8½	2	3	13·1
	8¾	2	5	9·3
	9	2	7	5·4
	9¼	2	9	1·6
	9½	2	10	13·7
	9¾	2	12	9·9
	10	2	14	6·0
	10¼	2	16	2·2
	10½	2	17	14·3
	10¾	2	19	10·5
	11	2	21	6·6
	11¼	2	23	2·8
	11½	2	24	15·0
	11¾	2	26	11·1
	12	3	0	7·3

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.
in.	in.				in.	in.				in.	in.
2¼	4½	1	5	8·5	2⅜	6	1	19	3·1	2½	7¾
	4¾	1	7	6·3		6¼	1	21	2·6		8
	5	1	9	4·1		6½	1	23	2·0		8¼
	5¼	1	11	1·9		6¾	1	25	1·5		8½
	5½	1	12	15·7		7	1	27	1·0		8¾
	5¾	1	14	13·5		7¼	2	1	0·4		9
	6	1	16	11·4		7½	2	2	15·9		9¼
	6¼	1	18	9·2		7¾	2	4	15·3		9½
	6½	1	20	7·0		8	2	6	14·8		9¾
	6¾	1	22	4·8		8¼	2	8	14·3		10
	7	1	24	2·6		8½	2	10	13·7		10¼
	7¼	1	26	0·4		8¾	2	12	13·2		10½
	7½	1	27	14·2		9	2	14	12·7		10¾
	7¾	2	1	12·0		9¼	2	16	12·1		11
	8	2	3	9·8		9½	2	18	11·6		11¼
	8¼	2	5	7·6		9¾	2	20	11·1		11½
	8½	2	7	5·4		10	2	22	10·5		11¾
	8¾	2	9	3·2		10¼	2	24	10·0		12
	9	2	11	1·0		10½	2	26	9·4		
	9¼	2	12	14·9		10¾	3	0	8·9	2⅝	5¼
	9½	2	14	12·7		11	3	2	8·4		5½
	9¾	2	16	10·5		11¼	3	4	7·8		5¾
	10	2	18	8·3		11½	3	6	7·3		6
	10¼	2	20	6·1		11¾	3	8	6·8		6¼
	10½	2	22	3·9		12	3	10	6·2		6½
	10¾	2	24	1·7							6¾
	11	2	25	15·5	2½	5	1	13	6·4		7
	11¼	2	27	13·3		5¼	1	15	7·5		7¼
	11½	3	1	11·1		5½	1	17	8·6		7½
	11¾	3	3	8·9		5¾	1	19	9·7		7¾
	12	3	5	6·7		6	1	21	10·8		8
						6¼	1	23	12·0		8¼
2⅜	4¾	1	9	5·8		6½	1	25	13·1		8½
	5	1	11	5·2		6¾	1	27	14·2		8¾
	5¼	1	13	4·7		7	2	1	15·3		9
	5½	1	15	4·2		7¼	2	4	0·4		9¼
	5¾	1	17	3·6		7½	2	6	1·6		9½

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
2⅝	9¾	3	0	12·2
	10	3	2	15·0
	10¼	3	5	1·8
	10½	3	7	4·6
	10¾	3	9	7·3
	11	3	11	10·1
	11¼	3	13	12·9
	11½	3	15	15·7
	11¾	3	18	2·4
	12	3	20	5·2
2¾	5½	1	22	1·5
	5¾	1	24	5·9
	6	1	26	10·3
	6¼	2	0	14·8
	6½	2	3	3·2
	6¾	2	5	7·6
	7	2	7	12·1
	7¼	2	10	0·5
	7½	2	12	4·9
	7¾	2	14	9·4
	8	2	16	13·8
	8¼	2	19	2·2
	8½	2	21	6·6
	8¾	2	23	11·1
	9	2	25	15·5
	9¼	3	0	3·9
	9½	3	2	8·4
	9¾	3	4	12·8
	10	3	7	1·2
	10¼	3	9	5·7
2¾	10½	3	11	10·1
	10¾	3	13	14·5
	11	3	16	3·0
	11¼	3	18	7·4
	11½	3	20	11·8
	11¾	3	23	0·3
	12	3	25	4·7
2⅞	5¾	1	26	12·0
	6	2	1	2·1
	6¼	2	3	8·2
	6½	2	5	14·2
	6¾	2	8	4·3
	7	2	10	10·4
	7¼	2	13	0·5
	7½	2	15	6·6
	7¾	2	17	12·7
	8	2	20	2·8
	8¼	2	22	8·9
	8½	2	24	15·0
	8¾	2	27	5·0
	9	3	1	11·1
	9¼	3	4	1·2
	9½	3	6	7·3
	9¾	3	8	13·4
	10	3	11	3·5
	10¼	3	13	9·6
	10½	3	15	15·7
	10¾	3	18	5·7
	11	3	20	11·8
2⅞	11¼	3	23	1·9
	11½	3	25	8·0
	11¾	3	27	14·1
	12	4	2	4·2
3	6	2	3	9·8
	6¼	2	6	1·6
	6½	2	8	9·3
	6¾	2	11	1·0
	7	2	13	8·8
	7¼	2	16	0·5
	7½	2	18	8·3
	7¾	2	21	0·0
	8	2	23	7·8
	8¼	2	25	15·5
	8½	3	0	7·3
	8¾	3	2	15·0
	9	3	5	6·7
	9¼	3	7	14·5
	9½	3	10	6·2
	9¾	3	12	14·0
	10	3	15	5·7
	10¼	3	17	13·5
	10½	3	20	5·2
	10¾	3	22	13·0
	11	3	25	4·7
	11¼	3	27	12·4
	11½	4	2	4·2
	11¾	4	4	11·9
	12	4	7	3·7

OBSERVATIONS ON TABLE II.

The weights here given, are in pounds, ounces, and decimal parts, avoirdupois ; and it will be seen, on inspecting the Table, that the first numbers in each page are those which apply to nut iron, and that the breadth increases by ⅛ of an inch as far as page 86, after which they rise by ¼ of an inch in breadth to the end. The last numbers in each page show the weight of a square foot, according to the respective thickness of each bar. Hence the weight of any length of a bar of rectangular iron may be ascertained simply, as follows :

Rule.—Multiply the tabular weight, according to the thickness and breadth, by the number of feet in the bar, the product will be the weight required.

Example.—In a bar of iron whose thickness is 2⅝ inches, the breadth 6¾ inches, and the length 18 feet, what is the weight thereof?

In the Table for 2⅝ inches thick, and opposite 6¾ inches, stand 2qrs. 2lbs. 10·9oz., being the weight of one lineal foot. Multiply this number by 18 feet, and we have as follows :

cwt.	qrs.	lbs.	oz.	
0	2	2	10·9	
			6	× 3=18
3	0	16	1·4	
			3	
9	1	20	4·2	Answer.

The foregoing Table of weights is obtained by following approximate rule :

Multiply the area of the end of the bar by length of one foot, and multiply that product by the product will be the weight in pounds avoirdu nearly.*

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* By this rule the weight of any length of ma *rectangular iron* may be ascertained nearly.

Required the weight of one lineal foot of iron, ½ inch thick, and 2¼ inches broad.

1·125 × 1 × 1·125 × 3·32=3·735 lbs. or 3 lbs. 11·76 oz.

he sake of expedition these Tables have been ed as follows. Having found by the above weight of one lineal foot for ⅛th of an inch to the thickness, it has been constantly til the breadth has attained to one foot.

Example.

then

25=·015625 × 3·32=·05187500 lbs. × 16=·83 oz.

Here ·83

+ ·83

Ounce 1·66=¼ inch broad.

+ ·83

2·49=⅜

+ ·83

3·32=½

+ ·83

4·15=⅝

+ ·83

4·98=¾

+ ·83

5·81=⅞

+ ·83

6·64=1 inch broad.

he Tables advancing by ¼ of an inch in breadth are ed in the same manner as the above.

TABLE III.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF ROUND BAR IRON,

in Avoirdupois qrs. lbs. oz., from ⅛th of an Inch to 12 Inche
Diameter, advancing by ⅛th of an Inch.

Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.
⅛	0	0	0·4	4⅛	1	16	4·1	8⅛	6	3	10·1
¼	0	0	2·6	4¼	1	18	15·8	8¼	6	8	15·4
⅜	0	0	5·8	4⅜	1	21	12·6	8⅜	6	14	5·8
½	0	0	10·4	4½	1	24	10·8	8½	6	19	13·6
⅝	0	1	0·1	4⅝	1	27	10·2	8⅝	6	25	6·7
¾	0	1	7·3	4¾	2	2	11·0	8¾	7	3	1·0
⅞	0	1	15·8	4⅞	2	5	13·1	8⅞	7	8	12·7
1	0	2	9·4	5	2	9	0·6	9	7	14	9·6
1⅛	0	3	4·8	5⅛	2	12	5·2	9⅛	7	20	7·8
1¼	0	4	1·1	5¼	2	15	11·0	9¼	7	26	7·4
1⅜	0	4	14·7	5⅜	2	19	2·4	9⅜	8	4	8·2
1½	0	5	13·7	5½	2	22	11·0	9½	8	10	10·4
1⅝	0	6	13·9	5⅝	2	26	4·8	9⅝	8	16	13·8
1¾	0	7	15·5	5¾	3	2	0·1	9¾	8	23	2·6
1⅞	0	9	2·4	5⅞	3	5	12·6	9⅞	9	1	8·6
2	0	10	6·5	6	3	9	10·4	10	9	8	0·0
2⅛	0	11	12·0	6⅛	3	13	8·6	10⅛	9	14	8·6
2¼	0	13	1·7	6¼	3	17	9·0	10¼	9	21	2·6
2⅜	0	14	10·7	6⅜	3	21	10·6	10⅜	9	27	13·8
2½	0	16	4·1	6½	3	25	13·6	10½	10	6	10·4
2⅝	0	17	14·8	6⅝	4	2	1·8	10⅝	10	13	8·2
2¾	0	19	9·6	6¾	4	6	7·4	10¾	10	20	7·4
2⅞	0	21	8·0	6⅞	4	11	1·4	10⅞	10	27	7·8
3	0	23	6·5	7	4	15	6·4	11	11	6	9·6
3⅛	0	25	6·4	7⅛	4	19	15·5	11⅛	11	13	12·6
3¼	0	27	7·6	7¼	4	24	10·6	11¼	11	21	1·0
3⅜	1	1	10·0	7⅜	5	1	6·7	11⅜	12	0	6·6
3½	1	3	13·9	7½	5	6	4·0	11½	12	7	13·6
3⅝	1	6	2·8	7⅝	5	11	2·6	11⅝	12	15	5·8
3¾	1	8	9·2	7¾	5	16	2·7	11¾	12	22	15·4
3⅞	1	11	0·9	7⅞	5	21	3·7	11⅞	13	2	10·2
4	1	13	9·9	8	5	26	6·4	12	13	10	6·4

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* James Foden.

TABLE IV.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF SQUARE BAR IRON,

in Avoirdupois qrs. lbs. oz., from ⅛th of an Inch to 12 Inches, advancing by ⅛th of an Inch.

Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.
⅛	0	0	0·8	4⅛	2	0	7·8	8⅛	7	23	2·7
¼	0	0	3·3	4¼	2	3	14·1	8¼	8	1	15·4
⅜	0	0	7·4	4⅜	2	7	6·4	8⅜	8	8	13·8
½	0	0	13·2	4½	2	11	3·7	8½	8	15	13·9
⅝	0	1	5·1	4⅝	2	14	13·6	8⅝	8	22	15·6
¾	0	1	13·8	4¾	2	18	14·3	8¾	9	2	2·0
⅞	0	2	8·6	4⅞	2	22	15·1	8⅞	9	9	8·0
1	0	3	4·9	5	2	27	0·0	9	9	16	14·7
1⅛	0	4	3·2	5⅛	3	3	3·2	9⅛	9	24	7·1
1¼	0	5	2·7	5¼	3	7	8·1	9¼	10	4	1·0
1⅜	0	6	4·1	3⅜	3	11	14·2	9⅜	10	11	12·7
1½	0	7	7·5	5½	3	16	6·8	9½	10	19	10·0
1⅝	0	8	12·0	5⅝	3	21	0·9	9⅝	10	27	9·0
1¾	0	10	1·6	5¾	3	25	12·2	9¾	11	7	9·7
1⅞	0	11	10·4	5⅞	4	2	8·1	9⅞	11	15	12·0
2	0	13	4·5	6	4	7	8·3	10	11	24	0·0
2⅛	0	14	15·4	6⅛	4	12	8·8	10⅛	12	4	5·6
2¼	0	16	12·9	6¼	4	17	11·0	10¼	12	12	12·9
2⅜	0	18	11·0	6⅜	4	22	14·8	10⅜	12	21	5·8
2½	0	20	12·0	6½	5	0	4·3	10½	13	2	0·4
2⅝	0	22	13·1	6⅝	5	5	11·4	10⅝	13	10	12·7
2¾	0	25	1·7	6¾	5	11	4·2	10¾	13	19	10·6
2⅞	0	27	6·4	6⅞	5	16	14·7	10⅞	14	0	10·2
3	1	1	14·1	7	5	22	10·8	11	14	9	11·5
3⅛	1	4	5·6	7⅛	6	0	8·6	11⅛	14	18	14·4
3¼	1	6	15·6	7¼	6	6	8·1	11¼	15	0	3·0
3⅜	1	9	11·6	7⅜	6	12	9·2	11⅜	15	9	9·2
3½	1	12	9·1	7½	6	18	12·0	11½	15	19	1·1
3⅝	1	15	8·3	7⅝	6	25	0·4	11⅝	16	0	10·6
3¾	1	18	9·1	7¾	7	3	6·5	11¾	16	10	5·8
3⅞	1	21	12·6	7⅞	7	9	14·2	11⅞	16	20	2·7
4	1	25	1·9	8	7	16	7·6	12	17	2	1·2

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* James Foden.

OBSERVATIONS ON TABLES III. AND IV.

The Tables of the weight of round and square l of malleable iron have been obtained by the follow approximate rules :

Rule 1.—For round bars. Multiply the squar the diameter in inches by the length in feet, and t product by 2·6. The product will be the weigh pounds avoirdupois, nearly.

Rule 2.—For square bars. Multiply the are the end of the bar in inches by the length in f and that by 3·32. The product will be the we in pounds avoirdupois, nearly.

Example 1.—What is the weight of a round ba malleable iron 4½ feet long, and 2¼ inches in meter ?

$2·25^2 \times 4·5 = 22·78125 \times 2·6 = 59·23125$ lbs. = 59 lbs. 3·7

Example 2.—Required the weight of a square of malleable iron whose length is 7¼ feet, and inch square.

$1·5^2 \times 7·25 = 16·3125 \times 3·32 = 54·1575$ lbs. = 54 lbs. 2·52

J.

TABLE V.*

CONTAINING THE CIRCUMFERENCES FOR ANGLED IRON HOOPS,

From 6 Inches to 6 Feet Diameter, advancing by an Eighth of an Inch.

ANGLE OUTSIDE.

Diam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
6	1	5½		10	2	5¼	1	2	3	5	1	6	4	4¾
⅛	1	5⅞		⅛	2	5⅝		⅛	3	5⅛		⅛	4	5⅛
¼	1	6¼		¼	2	6		¼	3	5¾		¼	4	5⅜
⅜	1	6⅝		⅜	2	6⅜		⅜	3	6⅛		⅜	4	5¾
½	1	7		½	2	6¾		½	3	6½		½	4	6⅛
⅝	1	7⅜		⅝	2	7⅛		⅝	3	6⅞		⅝	4	6½
¾	1	7¾		¾	2	7½		¾	3	7⅛		¾	4	6⅞
⅞	1	8⅛		⅞	2	7⅞		⅞	3	7½		⅞	4	7¼
7	1	8½		11	2	8⅛	1	3	3	7⅞	1	7	4	7⅝
⅛	1	8⅞		⅛	2	8½		⅛	3	8¼		⅛	4	8
¼	1	9¼		¼	2	8⅞		¼	3	8⅝		¼	4	8⅜
⅜	1	9½		⅜	2	9¼		⅜	3	9		⅜	4	8¾
½	1	9⅞		½	2	9⅝		½	3	9⅜		½	4	9⅛
⅝	1	10¼		⅝	2	10		⅝	3	9¾		⅝	4	9½
¾	1	10⅝		¾	2	10⅜		¾	3	10⅛		¾	4	9⅞
⅞	1	11		⅞	2	10¾		⅞	3	10½		⅞	4	10¼
8	1	11⅜	1	0	2	11⅛	1	4	3	10⅞	1	8	4	10⅝
⅛	1	11¾		⅛	2	11½		⅛	3	11¼		⅛	4	11
¼	2	0⅛		¼	2	11⅞		¼	3	11⅝		¼	4	11⅜
⅜	2	0½		⅜	3	0¼		⅜	3	11⅞		⅜	4	11⅝
½	2	0⅞		½	3	0⅝		½	4	0¼		½	5	0
⅝	2	1¼		⅝	3	1		⅝	4	0⅝		⅝	5	0⅜
¾	2	1⅝		¾	3	1⅜		¾	4	1		¾	5	0¾
⅞	2	2		⅞	3	1¾		⅞	4	1⅜		⅞	5	1⅛
9	2	2⅜	1	1	3	2	1	5	4	1¾	1	9	5	1½
⅛	2	2⅝		⅛	3	2⅜		⅛	4	2⅛		⅛	5	1⅞
¼	2	3		¼	3	2¾		¼	4	2½		¼	5	2¼
⅜	2	3⅜		⅜	3	3⅛		⅜	4	2⅞		⅜	5	2⅝
½	2	3¾		½	3	3½		½	4	3¼		½	5	3
⅝	2	4⅛		⅝	3	3⅞		⅝	4	3⅝		⅝	5	3⅜
¾	2	4½		¾	3	4¼		¾	4	4		¾	5	3¾
⅞	2	4⅞		⅞	3	4⅝		⅞	4	4⅜		⅞	5	4

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* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Dia
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
1	10	5	4⅜	2	3	6	7⅛	2	8	7	9¾	3
	⅛	5	4¾		⅛	6	7½		⅛	7	10⅛	
	¼	5	5⅛		¼	6	7⅞		¼	7	10½	
	⅜	5	5½		⅜	6	8⅛		⅜	7	10⅞	
	½	5	5⅞		½	6	8½		½	7	11¼	
	⅝	5	6¼		⅝	6	8⅞		⅝	7	11⅝	
	¾	5	6⅝		¾	6	9¼		¾	8	0	
	⅞	5	7		⅞	6	9⅝		⅞	8	0⅜	
1	11	5	7⅜	2	4	6	10	2	9	8	0⅝	3
	⅛	5	7¾		⅛	6	10⅜		⅛	8	1	
	¼	5	8⅛		¼	6	10¾		¼	8	1⅜	
	⅜	5	8½		⅜	6	11⅛		⅜	8	1¾	
	½	5	8⅞		½	6	11½		½	8	2⅛	
	⅝	5	9¼		⅝	6	11⅞		⅝	8	2½	
	¾	5	9⅝		¾	7	0¼		¾	8	2⅞	
	⅞	5	9⅞		⅞	7	0⅝		⅞	8	3¼	
2	0	5	10¼	2	5	7	1	2	10	8	3⅝	3
	⅛	5	10⅝		⅛	7	1⅜		⅛	8	4	
	¼	5	11		¼	7	1¾		¼	8	4⅜	
	⅜	5	11⅜		⅜	7	2		⅜	8	4¾	
	½	5	11¾		½	7	2⅜		½	8	5⅛	
	⅝	6	0⅛		⅝	7	2¾		⅝	8	5½	
	¾	6	0½		¾	7	3⅛		¾	8	5¾	
	⅞	6	0⅞		⅞	7	3½		⅞	8	6⅛	
2	1	6	1¼	2	6	7	3⅞	2	11	8	6½	3
	⅛	6	1⅝		⅛	7	4¼		⅛	8	6⅞	
	¼	6	2		¼	7	4⅝		¼	8	7¼	
	⅜	6	2⅜		⅜	7	5		⅜	8	7⅝	
	½	6	2¾		½	7	5⅜		½	8	8	
	⅝	6	3		⅝	7	5¾		⅝	8	8⅜	
	¾	6	3⅜		¾	7	6⅛		¾	8	8¾	
	⅞	6	3¾		⅞	7	6½		⅞	8	9⅛	
2	2	6	4⅛	2	7	7	6⅞	3	0	8	9½	3
	⅛	6	4½		⅛	7	7⅛		⅛	8	9⅞	
	¼	6	4⅞		¼	7	7½		¼	8	10¼	
	⅜	6	5¼		⅜	7	7⅞		⅜	8	10⅝	
	½	6	5⅝		½	7	8¼		½	8	11	
	⅝	6	6		⅝	7	8⅝		⅝	8	11¼	
	¾	6	6⅜		¾	7	9		¾	8	11⅝	
	⅞	6	6¾		⅞	7	9⅜		⅞	9	0	

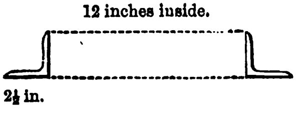
Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In
3	6	10	3	3	11	11	5¾	4	4	12	8⅜	4	9	13	11
	⅛	10	3⅜		⅛	11	6⅛		⅛	12	8¾		⅛	13	11
	¼	10	3¾		¼	11	6½		¼	12	9⅛		¼	13	11
	⅜	10	4⅛		⅜	11	6⅞		⅜	12	9½		⅜	14	0
	½	10	4½		½	11	7⅛		½	12	9⅞		½	14	0
	⅝	10	4⅞		⅝	11	7½		⅝	12	10¼		⅝	14	0
	¾	10	5¼		¾	11	7⅞		¾	12	10½		¾	14	1
	⅞	10	5⅝		⅞	11	8¼		⅞	12	10⅞		⅞	14	1
3	7	10	6	4	0	11	8⅝	4	5	12	11¼	4	10	14	2
	⅛	10	6⅜		⅛	11	9		⅛	12	11⅝		⅛	14	2
	¼	10	6¾		¼	11	9⅜		¼	13	0		¼	14	2
	⅜	10	7⅛		⅜	11	9¾		⅜	13	0⅜		⅜	14	3
	½	10	7½		½	11	10⅛		½	13	0¾		½	14	3
	⅝	10	7⅞		⅝	11	10½		⅝	13	1⅛		⅝	14	3
	¾	10	8¼		¾	11	10⅞		¾	13	1½		¾	14	4
	⅞	10	8½		⅞	11	11¼		⅞	13	1⅞		⅞	14	4
3	8	10	8⅞	4	1	11	11⅝	4	6	13	2¼	4	11	14	4
	⅛	10	9¼		⅛	12	0		⅛	13	2⅝		⅛	14	5
	¼	10	9⅝		¼	12	0¼		¼	13	3		¼	14	5
	⅜	10	10		⅜	12	0⅝		⅜	13	3⅜		⅜	14	6
	½	10	10⅜		½	12	1		½	13	3¾		½	14	6
	⅝	10	10¾		⅝	12	1⅜		⅝	13	4⅛		⅝	14	6
	¾	10	11⅛		¾	12	1¾		¾	13	4⅜		¾	14	7
	⅞	10	11½		⅞	12	2⅛		⅞	13	4¾		⅞	14	7
3	9	10	11⅞	4	2	12	2½	4	7	13	5⅛	5	0	14	7
	⅛	11	0¼		⅛	12	2⅞		⅛	13	5½		⅛	14	8
	¼	11	0⅝		¼	12	3¼		¼	13	5⅞		¼	14	8
	⅜	11	1		⅜	12	3⅝		⅜	13	6¼		⅜	14	8
	½	11	1⅜		½	12	4		½	13	6⅝		½	14	9
	⅝	11	1¾		⅝	12	4⅜		⅝	13	7		⅝	14	9
	¾	11	2		¾	12	4¾		¾	13	7⅜		¾	14	10
	⅞	11	2⅜		⅞	12	5⅛		⅞	13	7¾		⅞	14	10
3	10	11	2¾	4	3	12	5½	4	8	13	8⅛	5	1	14	10
	⅛	11	3⅛		⅛	12	5¾		⅛	13	8½		⅛	14	11
	¼	11	3½		¼	12	6⅛		¼	13	8⅞		¼	14	11
	⅜	11	3⅞		⅜	12	6½		⅜	13	9¼		⅜	14	11
	½	11	4¼		½	12	6⅞		½	13	9⅝		½	15	0
	⅝	11	4⅝		⅝	12	7¼		⅝	13	9⅞		⅝	15	0
	¾	11	5		¾	12	7⅝		¾	13	10¼		¾	15	
	⅞	11	5⅜		⅞	12	8		⅞	13	10⅝		⅞	15	

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Ci
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
5	2	15	1⅝	5	5	15	10½	5	8	16	7¼	5	10	17
	⅛	15	2		⅛	15	10⅞		⅛	16	7⅝		⅛	17
	¼	15	2⅜		¼	15	11¼		¼	16	8		¼	17
	⅜	15	2¾		⅜	15	11⅝		⅜	16	8⅜		⅜	17
	½	15	3⅛		½	16	0		½	16	8¾		½	17
	⅝	15	3½		⅝	16	0¼		⅝	16	9⅛		⅝	17
	¾	15	3⅞		¾	16	0⅝		¾	16	9½		¾	17
	⅞	15	4¼		⅞	16	1		⅞	16	9⅞		⅞	17
5	3	15	4⅝	5	6	16	1⅜	5	9	16	10¼	5	11	17
	⅛	15	5		⅛	16	1¾		⅛	16	10½		⅛	17
	¼	15	5⅜		¼	16	2⅛		¼	16	10⅞		¼	17
	⅜	15	5¾		⅜	16	2½		⅜	16	11¼		⅜	17
	½	15	6⅛		½	16	2⅞		½	16	11⅝		½	17
	⅝	15	6½		⅝	16	3¼		⅝	17	0		⅝	17
	¾	15	6⅞		¾	16	3⅝		¾	17	0⅜		¾	17
	⅞	15	7⅛		⅞	16	4		⅞	17	0¾		⅞	17
5	4	15	7½	5	7	16	4⅜					6	0	17
	⅛	15	7⅞		⅛	16	4¾							
	¼	15	8¼		¼	16	5⅛							
	⅜	15	8⅝		⅜	16	5⅜							
	½	15	9		½	16	5¾							
	⅝	15	9⅜		⅝	16	6⅛							
	¾	15	9¾		¾	16	6½							
	⅞	15	10⅛		⅞	16	6⅞							

OBSERVATIONS ON TABLE V.

As this Table, together with the following one, will be useful to those smiths who chiefly work angled iron, it will be necessary to remark, that the observation made on Table I., respecting adding the thickness of the iron to the diameter, must also be attended to in this, with this difference,—the breadth of the angle must be added to the diameter.

Example.—Suppose, as in the following sectional figure, a hoop is wanted to be made of 2½-inch angled iron, whose diameter inside must be 12 inches. Here the 2½ inches must be added to the 12 inches, which raises the number to 1 foot 2½ inches. Looking into the Table, I find the circumference, or length of iron requisite for the hoop, is 3 feet 6½ inches.



J. F.

TABLE VI.*

CONTAINING THE CIRCUMFERENCES FOR ANGLED I HOOPS,

From 6 Inches to 6 Feet Diameter, advancing by an Eighth of an

ANGLE INSIDE.

Diam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Ci
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
6	1	8½		10	2	10¼	1	2	3	11⅞	1	6	5
⅛	1	8¾		⅛	2	10⅝		⅛	4	0⅜		⅛	5
¼	1	9⅜		¼	2	11		¼	4	0¾		¼	5
⅜	1	9¾		⅜	2	11½		⅜	4	1⅛		⅜	5
½	1	10¼		½	2	11⅞		½	4	1⅝		½	5
⅝	1	10⅝		⅝	3	0⅜		⅝	4	2		⅝	5
¾	1	11⅛		¾	3	0¾		¾	4	2½		¾	5
⅞	1	11½		⅞	3	1¼		⅞	4	2⅞		⅞	5
7	1	11⅞		11	3	1⅝	1	3	4	3⅜	1	7	5
⅛	2	0⅜		⅛	3	2		⅛	4	3¾		⅛	5
¼	2	0¾		¼	3	2½		¼	4	4⅛		¼	5
⅜	2	1¼		⅜	3	2⅞		⅜	4	4⅝		⅜	5
½	2	1⅝		½	3	3⅜		½	4	5		½	5
⅝	2	2		⅝	3	3¾		⅝	4	5½		⅝	5
¾	2	2½		¾	3	4¼		¾	4	5⅞		¾	5
⅞	2	2⅞		⅞	3	4⅝		⅞	4	6¼		⅞	5
8	2	3⅜	1	0	3	5	1	4	4	6¾	1	8	
⅛	2	3¾		⅛	3	5½		⅛	4	7⅛		⅛	
¼	2	4¼		¼	3	5⅞		¼	4	7⅝		¼	
⅜	2	4⅝		⅜	3	6⅜		⅜	4	8		⅜	
½	2	5		½	3	6¾		½	4	8½		½	
⅝	2	5½		⅝	3	7⅛		⅝	4	8⅞		⅝	
¾	2	5⅞		¾	3	7⅝		¾	4	9⅜		¾	
⅞	2	6⅜		⅞	3	8		⅞	4	9¾		⅞	
9	2	6¾	1	1	3	8½	1	5	4	10⅛	1	9	
⅛	2	7¼		⅛	3	8⅞		⅛	4	10⅝		⅛	
¼	2	7⅝		¼	3	9⅜		¼	4	11		¼	
⅜	2	8		⅜	3	9¾		⅜	4	11½		⅜	
½	2	8½		½	3	10⅛		½	4	11⅞		½	
⅝	2	8⅞		⅝	3	10⅝		⅝	5	0¼		⅝	
¾	2	9⅜		¾	3	11		¾	5	0¾		¾	
⅞	2	9¾		⅞	3	11⅛		⅞	5	1⅛		⅞	

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* James Foden.

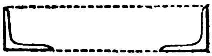
iam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
10	6	3¼	2	3	7	8⅜	2	8	9	1½	3	1	10	6⅝
⅛	6	3¾		⅛	7	8⅞		⅛	9	2		⅛	10	7⅛
¼	6	4⅛		¼	7	9¼		¼	9	2⅜		¼	10	7½
⅜	6	4⅝		⅜	7	9¾		⅜	9	2⅞		⅜	10	8
½	6	5		½	7	10⅛		½	9	3¼		½	10	8⅜
⅝	6	5⅜		⅝	7	10½		⅝	9	3⅝		⅝	10	8¾
¾	6	5⅞		¾	7	11		¾	9	4⅛		¾	10	9¼
⅞	6	6¼		⅞	7	11⅜		⅞	9	4½		⅞	10	9⅝
11	6	6¾	2	4	7	11¾	2	9	9	5	3	2	10	10⅛
⅛	6	7⅛		⅛	8	0¼		⅛	9	5⅜		⅛	10	10½
¼	6	7⅝		¼	8	0¾		¼	9	5⅞		¼	10	11
⅜	6	8		⅜	8	1⅛		⅜	9	6¼		⅜	10	11⅜
½	6	8⅜		½	8	1½		½	9	6⅝		½	10	11¾
⅝	6	8⅞		⅝	8	2		⅝	9	7⅛		⅝	11	0¼
¾	6	9¼		¾	8	2⅜		¾	9	7½		¾	11	0⅝
⅞	6	9¾		⅞	8	2¾		⅞	9	8		⅞	11	1⅛
0	6	10⅛	2	5	8	3¼	2	10	9	8⅜	3	3	11	1½
⅛	6	10½		⅛	8	3⅝		⅛	9	8⅞		⅛	11	2
¼	6	11		¼	8	4⅛		¼	9	9¼		¼	11	2⅜
⅜	6	11⅜		⅜	8	4½		⅜	9	9⅝		⅜	11	2¾
½	6	11⅞		½	8	5		½	9	10⅛		½	11	3¼
⅝	7	0¼		⅝	8	5½		⅝	9	10½		⅝	11	3⅝
¾	7	0¾		¾	8	5⅞		¾	9	11		¾	11	4⅛
⅞	7	1⅛		⅞	8	6¼		⅞	9	11⅜		⅞	11	4½
1	7	1⅝	2	6	8	6¾	2	11	9	11⅞	3	4	11	5
⅛	7	2		⅛	8	7⅛		⅛	10	0¼		⅛	11	5⅜
¼	7	2⅜		¼	8	7½		¼	10	0⅝		¼	11	5¾
⅜	7	2⅞		⅜	8	8		⅜	10	1⅛		⅜	11	6¼
½	7	3¼		½	8	8⅜		½	10	1½		½	11	6⅝
⅝	7	3¾		⅝	8	8⅞		⅝	10	2		⅝	11	7⅛
¾	7	4⅛		¾	8	9¼		¾	10	2⅜		¾	11	7½
⅞	7	4½		⅞	8	9⅝		⅞	10	2¾		⅞	11	8
2	7	5	2	7	8	10⅛	3	0	10	3¼	3	5	11	8⅜
⅛	7	5⅜		⅛	8	10½		⅛	10	3⅝		⅛	11	8¾
¼	7	5⅞		¼	8	11		¼	10	4⅛		¼	11	9¼
⅜	7	6¼		⅜	8	11⅜		⅜	10	4½		⅜	11	9⅝
½	7	6¾		½	8	11⅞		½	10	5		½	11	10⅛
⅝	7	7⅛		⅝	9	0¼		⅝	10	5⅜		⅝	11	10½
¾	7	7½		¾	9	0⅝		¾	10	5⅞		¾	11	10⅞
⅞	7	8		⅞	9	1⅛		⅞	10	6¼		⅞	11	1

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Ci
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
3	6	11	11¾	3	11	13	4⅞	4	4	14	10	4	9	16
	⅛	12	0¼		⅛	13	5⅜		⅛	14	10⅛		⅛	16
	¼	12	0⅝		¼	13	5¾		¼	14	10⅞		¼	16
	⅜	12	1⅛		⅜	13	6		⅜	14	11⅜		⅜	16
	½	12	1½		½	13	6⅝		½	14	11¾		½	16
	⅝	12	1⅞		⅝	13	7		⅝	15	0⅛		⅝	16
	¾	12	2⅜		¾	13	7½		¾	15	0⅝		¾	16
	⅞	12	2¾		⅞	13	7⅞		⅞	15	1		⅞	16
3	7	12	3¼	4	0	13	8⅜	4	5	15	1⅛	4	10	16
	⅛	12	3⅝		⅛	13	8¾		⅛	15	1⅞		⅛	16
	¼	12	4⅛		¼	13	9¼		¼	15	2¼		¼	16
	⅜	12	4½		⅜	13	9⅝		⅜	15	2¾		⅜	16
	½	12	4⅞		½	13	10		½	15	3⅛		½	16
	⅝	12	5⅜		⅝	13	10½		⅝	15	3⅝		⅝	16
	¾	12	5¾		¾	13	10⅞		¾	15	4		¾	16
	⅞	12	6¼		⅞	13	11⅜		⅞	15	4½		⅞	16
3	8	12	6⅝	4	1	13	11¾	4	6	15	4⅞	4	11	16
	⅛	12	7		⅛	14	0¼		⅛	15	5¼		⅛	16
	¼	12	7⅛		¼	14	0⅝		¼	15	5¾		¼	16
	⅜	12	7⅞		⅜	14	1		⅜	15	6⅛		⅜	16
	½	12	8⅜		½	14	1½		½	15	6⅝		½	16
	⅝	12	8¾		⅝	14	1⅞		⅝	15	7		⅝	17
	¾	12	9¼		¾	14	2⅜		¾	15	7½		¾	17
	⅞	12	9⅝		⅞	14	2¾		⅞	15	7⅞		⅞	17
3	9	12	10	4	2	14	3⅛	4	7	15	8¼	5	0	17
	⅛	12	10½		⅛	14	3½		⅛	15	8¾		⅛	17
	¼	12	10⅞		¼	14	4		¼	15	9⅛		¼	17
	⅜	12	11⅜		⅜	14	4½		⅜	15	9⅝		⅜	17
	½	12	11¾		½	14	4⅞		½	15	10		½	17
	⅝	13	0¼		⅝	14	5⅜		⅝	15	10½		⅝	17
	¾	13	0⅝		¾	14	5¾		¾	15	10⅞		¾	17
	⅞	13	1		⅞	14	6⅛		⅞	15	11¼		⅞	17
3	10	13	1½	4	3	14	6⅝	4	8	15	11¾	5	1	17
	⅛	13	1⅞		⅛	14	7		⅛	16	0⅛		⅛	17
	¼	13	2⅜		¼	14	7⅜		¼	16	0⅝		¼	17
	⅜	13	2¾		⅜	14	7⅞		⅜	16	1		⅜	17
	½	13	3¼		½	14	8⅜		½	16	1½		½	17
	⅝	13	3⅝		⅝	14	8¾		⅝	16	1⅞		⅝	
	¾	13	4		¾	14	9⅛		¾	16	2¼		¾	
	⅞	13	4⅛		⅞	14	9⅝		⅞	16	2¾		⅞	

iam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
2	17	8¼	5	5	18	6½	5	8	19	4⅞	5	10	19	11⅝
⅛	17	8¾		⅛	18	7		⅛	19	5¼		⅛	20	0⅛
¼	17	9⅛		¼	18	7⅜		¼	19	5¾		¼	20	0½
⅜	17	9½		⅜	18	7⅞		⅜	19	6⅛		⅜	20	1
½	17	10		½	18	8¼		½	19	6½		½	20	1⅜
⅝	17	10⅜		⅝	18	8¾		⅝	19	7		⅝	20	1⅞
¾	17	10⅞		¾	18	9⅛		¾	19	7⅜		¾	20	2¼
⅞	17	11¼		⅞	18	9½		⅞	19	7⅞		⅞	20	2⅝
3	17	11¾	5	6	18	10	5	9	19	8¼	5	11	20	3⅛
⅛	18	0⅛		⅛	18	10⅜		⅛	19	8⅝		⅛	20	3½
¼	18	0½		¼	18	10⅞		¼	19	9⅛		¼	20	4
⅜	18	1		⅜	18	11¼		⅜	19	9½		⅜	20	4⅜
½	18	1⅜		½	18	11¾		½	19	10		½	20	4¾
⅝	18	1⅞		⅝	19	0⅛		⅝	19	10⅜		⅝	20	5¼
¾	18	2¼		¾	19	0½		¾	19	10⅞		¾	20	5⅝
⅞	18	2¾		⅞	19	1		⅞	19	11¼		⅞	20	6⅛
4	18	3⅛	5	7	19	1⅜					6	0	20	6½
⅛	18	3½		⅛	19	1⅞								
¼	18	4		¼	19	2¼								
⅜	18	4⅜		⅜	19	2¾								
½	18	4⅞		½	19	3⅛								
⅝	18	5¼		⅝	19	3½								
¾	18	5¾		¾	19	4								
⅞	18	6⅛		⅞	19	4⅜								

OBSERVATIONS ON TABLE VI.

The observations respecting this Table are the reverse to those on the preceding one,—viz. the breadth of the angle must be taken from the diameter,—for this reason, that the diameter is taken from outside to outside of the ring, as in the following sectional figure :



Suppose a ring is to be made of angled iron, whose diameter outside is to be 12 inches, the breadth of the angle 2½ inches; then, by taking 2½ inches from 12 inches, we have left 9½ inches. Looking into the Table in the column of diameters, I find in the circumference column, opposite 9½ inches, 2 feet 8½ inches, which is the length of iron necessary for the ring.

It has been already observed, that between angled and plain iron a considerable difference exists with regard to the proportion of the circumference to the diameter: this is owing to the angle or flange on one side of the bar, and when the iron is formed into a hoop it contracts more or less, as the angle or flange may be inside or outside of the hoop. From repeated experiments on this subject, I have ascertained that the proportions of the diameters to the circumferences are as follows:—For the angle inside as 1:3·4248, and for the angle outside the hoop, as 1:2·9312::Diam:Circumf.

The method used in obtaining the numbers in these Tables of Circumferences of angled iron is, for the angle inside by adding $\frac{1}{8}$th of 3·4248, or ·4281 as a constant number; and for the angle outside, by constantly adding $\frac{1}{8}$th of 2·9312, or ·3664.

Example 1.—For a hoop with the angle or flange inside, beginning with 2 feet diameter.

3·4248 × 2=6·8496 feet, and ·8496 × 12=10·1952 inches, and this decimal ·1952 × $\frac{1}{8}$,

in.
6 feet 10·1952 × 8=$\frac{1}{8}$
+ ·4281
———
·6233 × 8=$\frac{1}{2}$
+ ·4281
———
6· in. 11·0514 × 8=$\frac{1}{20}$
+ ·4281
———
·4795 × 8=$\frac{3}{8}$, &c.

Ex. 2.—For a hoop whose angle or flange is outside, commencing with a diameter of 3 feet.

ft. in.
2·9312 × 3=8·7936, and ·7936 × 12=9·5232, and ·5232 × 8=$\frac{1}{2}$,

Hence, 8 feet 9 in. ·5232 × 8=$\frac{1}{2}$
·3664
———
·8896 × 8=$\frac{7}{8}$
·3664
———
10 in. ·2560 × 8=$\frac{1}{4}$
·3664
———
·6224 × 8=$\frac{5}{8}$, &c.

Problem.—To find the circumference of an ellipse, or an oval hoop or ring.

Rule.—Add the length of the two axes together, and multiply the sum by 1·5708 for the circumference; or as it may be used in the Table of Circumferences, take half the sum of the axes as a diameter, with the breadth of the iron added, and enter the Table of Circumferences where it will be found.

Ex. Required the circumference of an elliptical hoop, whose axes are 18½ and 13 inches, the thickness of the iron being 2½ inches.

18½
13
—
½)31½
—
15¾
+ 2½ thickness.
—
18¼ inches, the diameter.

Entering into the Table of Diameter with 18¼ inches, the circumference will be found to be 4 feet 9¼ inches.

In constructing elliptical hoops of angled iron, with the angle outside, reference must be made to the Tables for hoops of angled iron: the operation will be similar to the above example. But in hoops where the angle is inside, the thickness of the iron must be taken from half the sum of the axes.

Note.—It must be observed, that in the example given in the Observations on Table I., and also o hoops formed of angled iron, that those circum ferences are nothing more than the ends of the ir meeting together: therefore every smith must all for the thickening of the ends of the metal previo *to scarving the* same in order to weld it.

J. F.

roportional breadths for hexagonal or six-sided Nuts for wrought-iron Bolts.

ia. of bolts.	Breadth of nuts.	Dia. of bolts.	Breadth of nuts.
3/8	3/4 inch.	1 1/8	1 15/16 inch.
1/2	7/8 "	1 1/4	2 3/16 "
5/8	1 1/8 "	1 3/8	2 3/8 "
3/4	1 5/16 "	1 1/2	2 9/16 "
7/8	1 1/2 "	1 5/8	2 3/4 "
1	1 3/4 "	1 3/4	3 "

Note.—The thickness of the nut is equal the bolt's diameter.

WEIGHT OF A SUPERFICIAL FOOT OF PLATE OR SHEET IRON, COPPER, AND BRASS, IN POUNDS.

Thickness in parts of an inch.	Iron.	Thickness by the wire gauge. No.	Iron.	Copper.	Brass.	Thickness by the wire gauge. No.	Iron.	Copper.	Brass.
1/32	1·25	1	12·5	14·5	13·75	16	2·5	2·9	2·75
1/16	2·5	2	12	13·9	13·2	17	2·18	2·52	2·4
1/8	5	3	11	12·75	12·1	18	1·86	2·15	2·04
3/16	7·5	4	10	11·6	11	19	1·7	1·97	1·87
1/4	10	5	8·74	1·01	9·61	20	1·54	1·78	1·69
5/16	12·5	6	8·12	9·4	8·93	21	1·4	1·62	1·54
3/8	15	7	7·5	8·7	8·25	22	1·25	1·45	1·37
7/16	17·5	8	6·86	7·9	7·54	23	1·12	1·3	1·23
1/2	20	9	6·24	7·2	6·86	24	1	1·16	1·1
9/16	22·5	10	5·62	6·5	6·18	25	·9	1·04	·99
5/8	25	11	5	5·8	5·5	26	·8	·92	·88
11/16	27·5	12	4·38	5·08	4·81	27	·72	·83	·79
3/4	30	13	3·75	4·34	4·12	28	·64	·74	·7
7/8	35	14	3·12	3·6	3·43	29	·56	·64	·61
1	40	15	2·82	3·27	3·1	30	·5	·58	·55

Note.—No. 1 wire gauge equal $\frac{5}{16}$ths of an inch.
" 4 " $\frac{1}{4}$ "
" 7 " $\frac{3}{16}$ "
" 11 " $\frac{1}{8}$ "
" 16 " $\frac{1}{16}$ "
" 22 " $\frac{1}{32}$ "

The great variety of thicknesses into which copper is manufactured, causes in trade the weight to be named whereby to determine the thickness required, the unit being that of a common sheet, so designated, viz., 4 feet by 2 feet, in ℔s.; thus,

A 70℔ plate is $\frac{3}{16}$ths of an inch in thickness.
46½ " $\frac{1}{8}$ "
23 " $\frac{1}{16}$ "
11½ " $\frac{1}{32}$ "
6 " $\frac{1}{64}$ &c., &c.

The thickness of lead is also in common determined or understood by the weight, the unit being that of a square or superficial foot; thus,

4-℔ lead is $\frac{1}{16}$th of an inch in thickness.
6 " $\frac{1}{10}$ "
7½ " $\frac{1}{8}$ "
11 " $\frac{3}{16}$ "
15 " $\frac{1}{4}$ "

COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Bar iron being 1.		Cast iron being 1.		Dry deal being 1.	
Cast iron	= ·95	Bar iron	=1·07	Cast iron	=11·0
Steel	=1·02	Steel	=1·08	Cast tin	=11·2
Copper	=1·16	Brass	=1·16	Brass	=12·7
Brass	=1·09	Copper	=1·21	Copper	=13·3
Lead	=1·48	Lead	=1·56	Lead	=17·1

1. Suppose I have an article of plate iron, the weight of which is 728℔s., but want the same of copper, and of similar dimensions, what will be its weight?

$728 \times 1{\cdot}16 = 844{\cdot}48$ lbs.

A model of dry pine weighing 32½ lbs., and in ı the iron for its construction forms no material n of the weight, what may I anticipate its t to be in cast iron ?

$$32{\cdot}5 \times 11 = 357{\cdot}5 \text{ lbs.}$$

e.—It frequently occurs in the formation or construc- f models, that neither the quality nor condition of the r can be properly estimated, and in such cases it may ear enough approximation to reckon 10 lbs. of cast iron h lb. of model.

HTS OF 9-FEET LENGTHS OF CAST-IRON PIPES, OF VARIOUS DIAMETERS.

Thickness of metal.	Diameter of flange.	Thickness of flange.	Diameter of circle through holes.	Diameter and	number of holes.	Weight in cwts.	qrs.	lbs.
in.	in.	in.	in.	in.				
⅜	6½	9/16	4¾	⅝	4	0	3	0
⅜	7½	⅝	6	⅝	4	1	0	3
½	9½	¾	7¾	¾	4	1	3	5
½	10½	⅞	8¾	¾	4	2	1	12
⅝	12	⅞	10	¾	4	3	2	1
⅝	14	1	11¾	⅞	6	4	3	17
¾	15	1	12¾	1	6	5	2	9
¾	16½	1 1/16	14¼	1	6	6	1	12
¾	17½	1⅛	15½	1	6	7	0	0
⅞	19	1 3/16	16¾	1	6	8	3	24
⅞	20	1¼	17¾	1⅛	6	9	3	5
⅞	21	1¼	18¾	1⅛	6	10	2	0
⅞	22	1¼	19¾	1⅛	8	11	0	26
⅞	23	1¼	20¾	1⅛	8	12	0	25
⅞	24½	1 5/16	22	1¼	8	12	3	8
⅞	25½	1 5/16	23	1¼	8	13	2	17
1	26½	1⅜	24	1¼	8	16	1	15
1	28	1⅜	25	1⅜	8	17	2	13
1	29	1⅜	26	1⅜	8	18	0	26

Weights of Leaden Pipes.

¾-inch	bore	weighs	10	lbs. per yard.
1	„	„	12	„
1¼	„	„	16	„
1½	„	„	18	„
1¾	„	„	21	„
2	„	„	24	„

TO ASCERTAIN THE WEIGHTS OF PIPES OF VARIOUS METALS, AND ANY DIAMETER REQUIRED.

Thickness in parts of an inch.	Wrought iron.	Copper.		Lead.	
1/32	·326	11½ lbs. plate	·38	2 lbs. lead	·483
1/16	·653	23½ „	·76	4 „	·967
3/32	·976	35 „	1·14	5½ „	1·45
1/8	1·3	46½ „	1·52	8 „	1·933
5/32	1·627	58 „	1·9	9¼ „	2·417
3/16	1·95	70 „	2·28	11 „	2·9
7/32	2·277	80½ „	2·66	13 „	3·383
1/4	2·6	93 „	3·04	15 „	3·867

Rule.—To the interior diameter of the pipe, in inches, add the thickness of the metal; multiply the sum by the decimal numbers opposite the required thickness and under the metal's name; also by the length of the pipe in feet, and the product is the weight of the pipe in lbs.

1. Required the weight of a copper pipe whose interior diameter is 7½ inches, its length 6¼ feet, and the metal ⅛ of an inch in thickness.

7·5 + ·125=7·625 × 1·52 × 6·25=72·4 lbs.

2. What is the weight of a leaden pipe 18½ feet in length, 3 inches interior diameter, and the metal ¼ of an inch in thickness?

3 + ·25=3·25 × 3·867 × 18·5=232·5 lbs.

Note.—Weight of a cubic inch of

Lead	equal	·4103	lb
Copper, sheet	„	·3225	„
Brass do.	„	·3037	„
Iron do.	„	·279	„
Iron, cast	„	·263	„
Tin do.	„	·2636	„
Zinc do.	„	·26	„
Water	„	·03617	„

WEIGHT OF CAST-IRON BALLS.

Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.
2	1·10	6	29·72	10	137·71
2¼	1·57	6¼	33·62	10¼	148·28
2½	2·15	6½	37·80	10½	159·40
2¾	2·86	6¾	42·35	10¾	171·05
3	3·72	7	47·21	11	183·29
3¼	4·71	7¼	52·47	11¼	196·10
3½	5·80	7½	58·06	11½	209·43
3¾	7·26	7¾	64·09	11¾	223·40
4	8·81	8	70·49	12	237·94
4¼	10·57	8¼	77·32	12¼	253·13
4½	12·55	8½	84·56	12½	268·97
4¾	14·76	8¾	92·24	12¾	285·37
5	17·12	9	100·39	13	302·41
5¼	19·93	9¼	108·98	13¼	320·80
5½	22·91	9½	118·06	13½	338·81
5¾	26·18	9¾	127·63	13¾	357·93

1. What will be the weight of a hollow ball or shell f cast iron, the external diameter being 9½ and in-rnal diameter 8¾ inches?

Opposite 9½ are 118·06, and
Opposite 8¾ are 92·24, subtract

25·82 lbs., weight required.

2. *Requiring to remove* a cast-iron ball 37·8 lbs. in

weight, and in diameter 6½ inches, and replace it by one of lead of an equal weight, what must be the diameter of the leaden ball?

Weight of lead to that of cast iron=1·56 (see Table, page 110). Then $\frac{6{\cdot}5^3}{1{\cdot}56}=\sqrt[3]{176}=5{\cdot}6$ inches, the diameter.

TABLES BY WHICH TO FACILITATE THE MENSURATION OF TIMBER.

1. *Flat or Board Measure.*

Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.
¼	·0208	4	·3334	8	·6667
½	·0417	4¼	·3542	8¼	·6875
¾	·0625	4½	·375	8½	·7084
1	·0834	4¾	·3958	8¾	·7292
1¼	·1042	5	·4167	9	·75
1½	·125	5¼	·4375	9¼	·7708
1¾	·1459	5½	·4583	9½	·7917
2	·1667	5¾	·4792	9¾	·8125
2¼	·1875	6	·5	10	·8334
2½	·2084	6¼	·5208	10¼	·8542
2¾	·2292	6½	·5416	10½	·875
3	·25	6¾	·5625	10¾	·8959
3¼	·2708	7	·5833	11	·9167
3½	·2916	7¼	·6042	11¼	·9375
3¾	·3125	7½	·625	11½	·9583
		7¾	·6458	11¾	·9792

Application and Use of the Table.

1. Required the number of square feet in a board or plank 16½ feet in length and 9¾ inches in breadth.

Opposite 9¾ is ·8125 × 16·5=13·4 square feet.

2. A board 1 foot 2¾ inches in breadth and 21 feet in length; what is its superficial content in square feet?

Opposite 2¾ is ·2292, to which add the 1 foot; then *1·2292* × 21=25·8 square feet.

3. In a board 15½ inches at one end, 9 inches at the other, and 14½ feet in length, how many square feet?

$$\frac{15{\cdot}5+9}{2}=12\tfrac{1}{4}, \text{ or } 1{\cdot}0208\text{; and } 1{\cdot}0208\times14{\cdot}5=14{\cdot}8 \text{ sq. ft.}$$

2. *Cubic or Solid Measure.*

Mean ¼ girt in inches.	Cubic feet in each lineal foot.	Mean ¼ girt in inches.	Cubic feet in each lineal foot.	Mean ¼ girt in inches.	Cubic feet in each lineal foot.
6	·25	14	1·361	22	3·362
6¼	·272	14¼	1·41	22¼	3·438
6½	·294	14½	1·46	22½	3·516
6¾	·317	14¾	1·511	22¾	3·598
7	·340	15	1·562	23	3·673
7¼	·364	15¼	1·615	23¼	3·754
7½	·39	15½	1·668	23½	3·835
7¾	·417	15¾	1·722	23¾	3·917
8	·444	16	1·777	24	4
8¼	·472	16¼	1·833	24¼	4·084
8½	·501	16½	1·89	24½	4·168
8¾	·531	16¾	1·948	24¾	4·254
9	·562	17	2·006	25	4·34
9¼	·594	17¼	2·066	25¼	4·428
9½	·626	17½	2·126	25½	4·516
9¾	·659	17¾	2·187	25¾	4·605
10	·694	18	2·25	26	4·694
10¼	·73	18¼	2·313	26¼	4·785
10½	·766	18½	2·376	26½	4·876
10¾	·803	18¾	2·442	26¾	4·969
11	·84	19	2·506	27	5·062
11¼	·878	19¼	2·574	27¼	5·158
11½	·918	19½	2·64	27½	5·252
11¾	·959	19¾	2·709	27¾	5·348
12	1·	20	2·777	28	5·444
12¼	1·042	20¼	2·898	28¼	5·542
12½	1·085	20½	2·917	28½	5·64
12¾	1·129	20¾	2·99	28¾	5·74
13	1·174	21	3·062	29	5·84
13¼	1·219	21¼	3·136	29¼	5·941
13½	1·265	21½	3·209	29½	6·044
13¾	1·313	21¾	3·285	29¾	6·146

In the cubic estimation of timber, custom has established the rule of ¼ the mean girt being the side of the square considered as the cross sectional dimensions; hence, multiply the number of cubic feet per lineal foot as in the Table of Cubic Measure opposite the ¼ girt, and the product is the solidity of the given dimensions in cubic feet.

Suppose the mean ¼ girt of a tree 21¼ inches, and its length 16 feet, what are its contents in cubic feet?

3·136 × 16=50·176 cubic feet.

Battens, Deals, and Planks, as imported into this country, are each similar in their various lengths, but differing in their widths and thicknesses, and hence their principal distinction: thus, a batten is 7 inches by 2½,—a deal 9 by 3,—and a plank 11 by 3,—these being what are termed the standard dimensions, by which they are bought and sold, the length of each being taken at 12 feet; therefore, in estimating for the proper value of any quantity, nothing more is required than their lineal dimensions, by which to ascertain the number of times 12 feet there are in the given whole.

Suppose I wish to purchase the following:

7 of 6 feet 6 × 7= 42 feet
5 „ 14 „ 14 × 5= 70 „
11 „ 19 „ 19 × 11=209 „
and 6 „ 21 „ 21 × 6=126 „

12)447(37·25 standard deals.

TABLE SHOWING THE NUMBER OF LINEAL FEET OF SCANTLING OF VARIOUS DIMENSIONS WHICH ARE EQUAL TO A CUBIC FOOT.

	In.	require in length	Ft.	In.
2 inches by	2		36	0
	2½		28	9
	3		24	0
	3½		20	7
	4		18	0
	4½		16	0
	5		14	5
	5½		13	1
	6		12	0
	6½		11	1
	7		10	3
	7½		9	7
	8		9	0
	8½		8	6
	9		8	0
	9½		7	7
	10		7	3
	10½		6	10
	11		6	6
	11½		6	4
	12		6	0
3 inches by	3		16	0
	3½		13	8
	4		12	0
	4½		10	8
	5		9	7
	5½		9	0
	6		8	0
	6½		7	4
	7		6	10
	7½		6	4
	8		6	0
	8½		5	8
	9		5	4
	9½		5	0
	10		4	10
	10½		4	6
	11		4	4
	11½		4	2
	12		4	0
4 inches by	4		9	0
	4½		8	0
	5		7	2
	5½		6	6
	6		6	0
	6½		5	6
	7		5	1
	7½		4	9
	8		4	6
	8½		4	3
	9		4	0
	9½		3	9
	10		3	7
	10½		3	5
	11		3	3
	11½		3	2
	12		3	0
5 inches by	5		5	9
	5½		5	3
	6		4	10
	6½		4	5
	7		4	1
	7½		3	10
	8		3	7
	8½		3	5
	9		3	2
	9½		3	0
	10		2	10
	10½		2	9
	11		2	8
	11½		2	6
	12		2	4
6 inches by	6		4	0
	6½		3	8
	7		3	5
	7½		3	2
	8		3	0
	8½		2	10
	9		2	8
6 inches by	9½		2	6
	10		2	5
	10½		2	3
	11		2	2
	11½		2	1
	12		2	0
7 inches by	7		2	11
	7½		2	9
	8		2	6
	8½		2	5
	9		2	3
	9½		2	2
	10		2	1
	10½		1	11
	11		1	10
	11½		1	9
	12		1	8
8 inches by	8		2	3
	8½		2	1
	9		2	0
	9½		1	10
	10		1	9
	10½		1	8
	11		1	7
	11½		1	7
	12		1	6
9 inches by	9		1	9
	9½		1	8
	10		1	7
	10½		1	6
	11		1	5
	11½		1	4
	12		1	4
10 in. by	10		1	5
	10½		1	4
	11		1	4
	11½		1	3

INSTRUMENTAL ARITHMETIC.

OR UTILITY OF THE SLIDE RULE.

THE slide rule is an instrument by which the greater portion of operations in arithmetic and mensuration may be advantageously performed, provided the lines of division and gauge-points be made properly correct, and their several values familiarly understood.

The lines of division are distinguished by the letters A B C D; A B and C being each divided alike, and containing what is termed a double radius, or double series of logarithmic numbers, each series being supposed to be divided into 1000 equal parts, and distributed along the radius in the following manner:

From 1 to	2	contains	301	of those parts, being the log. of	2.
,,	3	,,	477	,,	3.
,,	4	,,	602	,,	4.
,,	5	,,	699	,,	5.
,,	6	,,	778	,,	6.
,,	7	,,	845	,,	7.
,,	8	,,	903	,,	8.
,,	9	,,	954	,,	9.

1000 being the whole number.

The line D on the improved rules consists of only a single radius; and although of larger radius, the logarithmic series is the same, and disposed of along the *line in a similar* proportion, forming exactly a line of *square roots* to the numbers on the lines B C.

NUMERATION.

Numeration teaches us to estimate or properly value the numbers and divisions on the rule in an arithmetical form.

Their values are all entirely governed by the value set upon the first figure, and being decimally reckoned, advance tenfold from the commencement to the termination of each radius: thus, suppose 1 at the joint be one, the 1 in the middle of the rule is ten, and 1 at the end, one hundred: again, suppose 1 at the joint ten, 1 in the middle is 100, and 1 or 10 at the end is 1000, &c., the intermediate divisions on which complete the whole system of its notation.

TO MULTIPLY NUMBERS BY THE RULE.

Set 1 on B opposite to the multiplier on A; and against the number to be multiplied on B is the product on A.

Multiply 6 by 4.

Set 1 on B to 4 on A; and against 6 on B is 24 on A. The slide thus set, against 7 on B is 28 on A.

8 „ 32 „
9 „ 36 „
10 „ 40 „
12 „ 48 „
15 „ 60 „
25 „ 100, &c., &c.

TO DIVIDE NUMBERS UPON THE RULE.

Set the divisor on B to 1 on A; and against the number to be divided on B is the quotient on A.

Divide 63 by 3.

Set 3 on B to 1 on A; and against 63 on B is 21 on A.

PROPORTION, OR RULE OF THREE DIRECT.

Rule.—Set the first term on B to the second on A; and against the third upon B is the fourth upon A.

1. If four yards of cloth cost 38 shillings, what will 30 yards cost at the same rate?

Set 4 on B to 38 on A; and against 30 on B is 285 shillings on A.

2. Suppose I pay 31*s.* 6*d.* for three cwt of iron, at what rate is that per ton? 1 *ton*=20 *cwt.*

Set 3 upon B to 31·5 upon A; and against 20 upon B is 210 upon A.

RULE OF THREE INVERSE.

Rule.—Invert the slide, and the operation is the same as direct proportion.

1. I know that six men are capable of performing a certain given portion of work in eight days, but I want the same performed in three; how many men must there be employed?

Set 6 upon C to 8 upon A; and against 3 upon C is 16 upon A.

2. The lever of a safety-valve is 20 inches in length, and 5 inches between the fixed end and centre of the valve; what weight must there be placed on the end of the lever to equipoise a force or pressure of 40 ℔s. tending to raise the valve?

Set 5 upon C to 40 upon A; and against 20 on C is 10 on A.

3. If $8\frac{3}{4}$ yards of cloth, $1\frac{1}{2}$ yard in width, be a sufficient quantity, how much will be required of that which is only $\frac{7}{8}$ths in width, to effect the same purpose?

Set 1·5 on C to 8·75 on A; and against ·875 upon C is 15 yards *upon A.*

SQUARE AND CUBE ROOTS OF NUMBERS.

On the engineer's rule, when the lines C and D are equal at both ends, C is a table of squares, and D a table of roots, as

Squares	1	4	9	16	25	36	49	64	81	on C.
Roots	1	2	3	4	5	6	7	8	9	on D.

To find the geometrical mean proportion between two numbers.

Set one of the numbers upon C to the same number upon D; and against the other number upon C is the mean number or side of an equal square upon D.

Required the mean proportion between 20 and 45.

Set 20 upon C to 20 upon D; and against 45 upon C is 30 on D.

To cube any number, set the number upon C to 1 or 10 upon D; and against the same number upon D is the cube number upon C.

Required the cube of 4.

Set 4 upon C to 1 or 10 upon D; and against 4 upon D is 64 upon C.

To extract the cube root of any number, invert the slide, and set the number upon B to 1 or 10 upon D; and where two numbers of equal value coincide on the lines B D, is the root of the given number.

Required the cube root of 64.

Set 64 upon B to 1 or 10 upon D; and against 4 upon B is 4 upon D, or root of the given number.

On the common rule, when 1 in the middle of the line C is set opposite to 10 on D, then C is a table of squares, and D a table of roots.

To cube any number by this rule, set the number upon C to 10 upon D; and against the same number upon D is the cube upon C.

MENSURATION OF SURFACE.

1. *Squares, Rectangles, &c.*

Rule.—When the length is given in feet and the breadth in inches, set the breadth on B to 12 on A; and against the length on A is the content in square feet on B.

If the dimensions are all inches, set the breadth on B to 144 upon A; and against the length upon A is the number of square feet on B.

Required the content of a board 15 inches broad and 14 feet long.

Set 15 upon B to 12 upon A; and against 14 upon A is 17·5 square feet on B.

2. *Circles, Polygons, &c.*

Rule.—Set ·7854 upon C to 1 or 10 upon D; then will the lines C and D be a table of areas and diameters.

Areas	3·14	7·06	12·56	19·63	28·27	38·48	50·26	63·61	upon C.
Diam.	2	3	4	5	6	7	8	9	upon D.

In the common rule, set ·7854 on C to 10 on D; then C is a line or table of areas, and D of diameters, as before.

Set 7 upon B to 22 upon A; then B and A form or become a table of diameters and circumferences of circles.

Cir.	3·14	6·28	9·42	12·56	15·7	18·85	22	25·13	28·27	upon A.
Dia.	1	2	3	4	5	6	7	8	9	upon B.

Polygons from 3 to 12 sides.—Set the gauge-point upon C to 1 or 10 upon D; and against the length of one side upon D is the area upon C.

Sides	3	5	6	7	8	9	10	11	12
Gauge-points	·433	1·7	2·6	3·63	4·82	6·18	7·69	9·37	11·17

Required the area of an equilateral triangle, each side 12 inches in length.

Set ·433 upon C to 1 upon D; and against 12 upon D are 62·5 square inches upon C.

TABLE OF GAUGE-POINTS FOR THE ENGINEER'S RULE.

Names.	F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches	578	83	1728	106	1273	105	121
Cubic feet	1	144	1	1833	22	121	33
Imp. gallons	163	231	277	294	353	306	529
Water in lbs.	16	23	276	293	352	305	528
Gold ,,	814	1175	141	149	178	155	269
Silver ,,	15	216	261	276	334	286	5
Mercury ,,	118	169	203	216	258	225	389
Brass ,,	193	177	333	354	424	369	637
Copper ,,	18	26	319	331	397	345	596
Lead ,,	141	203	243	258	31	27	465
Wro^{t}.iron ,,	207	297	357	338	453	394	682
Cast iron ,,	222	32	384	407	489	424	733
Tin ,,	219	315	378	401	481	419	728
Steel ,,	202	292	352	372	448	385	671
Coal ,,	127	183	22	33	28	242	42
Marble ,,	591	85	102	116	13	113	195
Freestone ,,	632	915	11	1162	14	141	21

FOR THE COMMON SLIDE RULE.

Names.	F, F, F.	F, I, I,	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches	36	518	624	660	799	625	113
Cubic feet	625	9	108	114	138	119	206
Water in lbs.	10	144	174	184	22	191	329
Gold ,,	507	735	88	96	118	939	180
Silver ,,	938	136	157	173	208	173	354
Mercury ,,	738	122	127	132	162	141	242
Brass ,,	12	174	207	221	265	23	397
Copper ,,	112	163	196	207	247	214	371
Lead ,,	880	126	152	162	194	169	289
Wro^{t}.iron ,,	129	186	222	235	283	247	423
Cast iron ,,	139	2	241	254	304	265	458
Tin ,,	137	135	235	25	300	261	454
Steel ,,	136	183	22	233	278	239	418
Coal ,,	795	114	138	146	176	151	262
Marble ,,	370	53	637	725	81	72	121
Freestone ,,	*394*	*57*	69	728	873	755	132

MENSURATION OF SOLIDITY AND CAPACITY.

General rule.—Set the length upon B to the gauge-point upon A; and against the side of the square, or diameter on D, are the cubic contents, or weight in lbs. on C.

1. Required the cubic contents of a tree 30 feet in length, and 10 inches quarter girt.

Set 30 upon B to 144 (the gauge-point) upon A; and against 10 upon D is 20·75 feet upon C.

2. In a cylinder 9 inches in length, and 7 inches diameter, how many cubic inches?

Set 9 upon B to 1273 (the gauge-point) upon A; and against 7 on D is 346 inches on C.

3. What is the weight of a bar of cast iron 3 inches square, and 6 feet long?

Set 6 upon B to 32 (the gauge-point) upon A; and against 3 upon D is 168 lbs. upon C.

By the common rule.

4. Required the weight of a cylinder of wrought iron 10 inches long, and 5½ diameter.

Set 10 upon B to 283 (G. P^{t}.) upon A; and against 5½ upon D is 66·65 lbs. on C.

5. What is the weight of a dry rope 25 yards long, and 4 inches circumference?

Set 25 upon B to 47 (G. P^{t}.) upon A; and against 4 on D is 53·16 lbs. on C.

6. What is the weight of a short-linked chain 30 yards in length, and $\frac{6}{16}$ths of an inch in diameter?

Set 30 upon B to 52 (G. P^{t}.) upon A; and against 6 on D is *129·5 lbs. on C.*

LAND SURVEYING.

dimensions taken are in chains, the gauge-1 or 10; if in perches, 160; and if in yards, *Rule.* Set the length upon B to the gauge-. A; and against the breadth upon A is the in acres upon B.

quired the number of acres or contents of 0 chains 50 links in length, and 4 chains 40 breadth.

5 on B to 1 on A; and against 4·4 on A is 9 acres on B.

a piece of ground 440 yards long, and 44 ow many acres?

) upon B to 4840 on A; and against 44 on A is ι B.

POWER OF STEAM ENGINES.

ɜnsing Engines.—Rule. Set 3·5 on C to 10 on D is a line of diameters for cylinders, and C esponding number of horses' power; thus,

	4	5	6	8	10	12	16	20	25	30	40	50 on C.
.	10¾	12	13¼	15½	17	18¾	21½	24	26¾	29½	33¾	37¾ on D.

ame is effected on the common rule by setting o 12 on D.

ondensing Engines.—Rule. Set the pressure in lbs. per square inch on B to 4 upon A; nst the cylinder's diameter on D is the num-ɔrses' power upon C.

red the power of an engine, when the cylin-0 inches diameter and steam 30 lbs. per ıch.

on B to 4 on A; and against 20 on D is 30 horses' a.

The same is effected on the common rule by setting the force of the steam on B to 250 on A.

OF ENGINE BOILERS.

How many superficial feet are contained in a boiler 23 feet in length and 5½ in width?

Set 1 upon B to 23 upon A; and against 5·5 upon B is 126·5 square feet upon A.

If 5 square feet of boiler surface be sufficient for each horse-power, how many horses' power of engine is the boiler equal to?

Set 5 upon B to 126·5 upon A; and against 1 upon B is 25·5 upon A.

COMMERCIAL TABLES.

TABLE BY WHICH TO FACILITATE THE CALCULATION OF BRITISH MONEY.

	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
No.	at ¼*d.*			at ½*d.*			at ¾*d.*			at 1*d.*			at 1¼*d.*			at 1½*d.*			at 1¾*d.*		
2	0	0	0½	0	0	1	0	0	1½	0	0	2	0	0	2½	0	0	3	0	0	3½
3	0	0	0¾	0	0	1½	0	0	2¼	0	0	3	0	0	3¾	0	0	4½	0	0	5¼
4	0	0	1	0	0	2	0	0	3	0	0	4	0	0	5	0	0	6	0	0	7
5	0	0	1¼	0	0	2½	0	0	3¾	0	0	5	0	0	6¼	0	0	7½	0	0	8¾
6	0	0	1½	0	0	3	0	0	4½	0	0	6	0	0	7½	0	0	9	0	0	10½
7	0	0	1¾	0	0	3½	0	0	5¼	0	0	7	0	0	8¾	0	0	10½	0	1	0¼
8	0	0	2	0	0	4	0	0	6	0	0	8	0	0	10	0	1	0	0	1	2
9	0	0	2¼	0	0	4½	0	0	6¾	0	0	9	0	0	11¼	0	1	1½	0	1	3¾
10	0	0	2½	0	0	5	0	0	7½	0	0	10	0	1	0½	0	1	3	0	1	5½
11	0	0	2¾	0	0	5½	0	0	8¼	0	0	11	0	1	1¾	0	1	4½	0	1	7¼
12	0	0	3	0	0	6	0	0	9	0	1	0	0	1	3	0	1	6	0	1	9
13	0	0	3¼	0	0	6½	0	0	9¾	0	1	1	0	1	4¼	0	1	7½	0	1	10¾
14	0	0	3½	0	0	7	0	0	10½	0	1	2	0	1	5½	0	1	9	0	2	0½
15	0	0	3¾	0	0	7½	0	0	11¼	0	1	3	0	1	6¾	0	1	10½	0	2	2¼
16	0	0	4	0	0	8	0	1	0	0	1	4	0	1	8	0	2	0	0	2	4
17	0	0	4¼	0	0	8½	0	1	0¾	0	1	5	0	1	9¼	0	2	1½	0	2	5¾
18	0	0	4½	0	0	9	0	1	1½	0	1	6	0	1	10½	0	2	3	0	2	7½
19	0	0	4¾	0	0	9½	0	1	2¼	0	1	7	0	1	11¾	0	2	4½	0	2	9¼
20	0	0	5	0	0	10	0	1	3	0	1	8	0	2	1	0	2	6	0	2	11
30	0	0	7½	0	1	3	0	1	10½	0	2	6	0	3	1½	0	3	9	0	4	4½
40	0	0	10	0	1	8	0	2	6	0	3	4	0	4	2	0	5	0	0	5	10
50	0	1	0½	0	2	1	0	3	1½	0	4	2	0	5	2½	0	6	3	0	7	3½
60	0	1	3	0	2	6	0	3	9	0	5	0	0	6	3	0	7	6	0	8	9
70	0	1	5½	0	2	11	0	4	4½	0	5	10	0	7	3½	0	8	9	0	10	2½
80	0	1	8	0	3	4	0	5	0	0	6	8	0	8	4	0	10	0	0	11	8
90	0	1	10½	0	3	9	0	5	7½	0	7	6	0	9	4½	0	11	3	0	13	1½
100	0	2	1	0	4	2	0	6	3	0	8	4	0	10	5	0	12	6	0	14	7
200	0	4	2	0	8	4	0	12	6	0	16	8	1	0	10	1	5	0	1	9	2
300	0	6	3	0	12	6	0	18	9	1	5	0	1	11	3	1	17	6	2	3	9
400	0	8	4	0	16	8	1	5	0	1	13	4	2	1	8	2	10	0	2	18	4
500	0	10	5	1	0	10	1	11	3	2	1	8	2	12	1	3	2	6	3	12	11
600	0	12	6	1	5	0	1	17	6	2	10	0	3	2	6	3	15	0	4	7	6
700	0	14	7	1	9	2	2	3	9	2	18	4	3	12	11	4	7	6	5	2	1
800	0	16	8	1	13	4	2	10	0	3	6	8	4	3	4	5	0	0	5	16	8
900	0	18	9	1	17	6	2	16	3	3	15	0	4	13	9	5	12	6	6	11	3
1000	1	0	10	2	1	8	3	2	6	4	3	4	5	4	2	6	5	0	7	5	10
2000	2	1	8	4	3	4	6	5	0	8	6	8	10	8	4	12	10	0	14	11	8
3000	3	2	6	6	5	0	9	7	6	12	10	0	15	12	6	18	15	0	21	17	6
4000	4	3	4	8	6	8	12	10	0	16	13	4	20	16	8	25	0	0	29	3	4
5000	5	4	2	10	8	4	15	12	6	20	16	8	26	0	10	31	5	0	36	9	2
6000	6	5	0	12	10	0	18	15	0	25	0	0	31	5	0	37	10	0	43	15	0
7000	7	5	10	14	11	8	21	17	6	29	3	4	36	9	2	43	15	0	51	0	10
8000	8	6	8	16	13	4	25	0	0	33	6	8	41	13	4	50	0	0	58	6	8
9000	9	7	6	18	15	0	28	2	6	37	10	0	46	17	6	56	5	0	65	12	6

MONEY TABLE—CONTINUED.

No.	at 2d.			at 2¼d.			at 2½d.			at 2¾d.			at 3d.			at 3¼d.			at 3½d.		
	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
2	0	0	4	0	0	4½	0	0	5	0	0	5½	0	0	6	0	0	6½	0	0	7
3	0	0	6	0	0	6¾	0	0	7½	0	0	8¼	0	0	9	0	0	9¾	0	0	10½
4	0	0	8	0	0	9	0	0	10	0	0	11	0	1	0	0	1	1	0	1	2
5	0	0	10	0	0	11¼	0	1	0½	0	1	1¾	0	1	3	0	1	4¼	0	1	5½
6	0	1	0	0	1	1½	0	1	3	0	1	4½	0	1	6	0	1	7½	0	1	9
7	0	1	2	0	1	3¾	0	1	5½	0	1	7¼	0	1	9	0	1	10¾	0	2	0½
8	0	1	4	0	1	6	0	1	8	0	1	10	0	2	0	0	2	2	0	2	4
9	0	1	6	0	1	8¼	0	1	10½	0	2	0¾	0	2	3	0	2	5¼	0	2	7½
10	0	1	8	0	1	10½	0	2	1	0	2	3½	0	2	6	0	2	8½	0	2	11
11	0	1	10	0	2	0¾	0	2	3½	0	2	6¼	0	2	9	0	2	11¾	0	3	2½
12	0	2	0	0	2	3	0	2	6	0	2	9	0	3	0	0	3	3	0	3	6
13	0	2	2	0	2	5¼	0	2	8½	0	2	11¾	0	3	3	0	3	6¼	0	3	9½
14	0	2	4	0	2	7½	0	2	11	0	3	2½	0	3	6	0	3	9½	0	4	1
15	0	2	6	0	2	9¾	0	3	1½	0	3	5¼	0	3	9	0	4	0¾	0	4	4½
16	0	2	8	0	3	0	0	3	4	0	3	8	0	4	0	0	4	4	0	4	8
17	0	2	10	0	3	2¼	0	3	6½	0	3	10¾	0	4	3	0	4	7¼	0	4	11½
18	0	3	0	0	3	4½	0	3	9	0	4	1½	0	4	6	0	4	10½	0	5	3
19	0	3	2	0	3	6¾	0	3	11½	0	4	4¼	0	4	9	0	5	1¾	0	5	6½
20	0	3	4	0	3	9	0	4	2	0	4	7	0	5	0	0	5	5	0	5	10
30	0	5	0	0	5	7½	0	6	3	0	6	10½	0	7	6	0	8	1½	0	8	9
40	0	6	8	0	7	6	0	8	4	0	9	2	0	10	0	0	10	10	0	11	8
50	0	8	4	0	9	4½	0	10	5	0	11	5½	0	12	6	0	13	6½	0	14	7
60	0	10	0	0	11	3	0	12	6	0	13	9	0	15	0	0	16	3	0	17	6
70	0	11	8	0	13	1½	0	14	7	0	16	0½	0	17	6	0	18	11½	1	0	5
80	0	13	4	0	15	0	0	16	8	0	18	4	1	0	0	1	1	8	1	3	4
90	0	15	0	0	16	10½	0	18	9	1	0	7½	1	2	6	1	4	4½	1	6	3
100	0	16	8	0	18	9	1	0	10	1	2	11	1	5	0	1	7	1	1	9	2
200	1	13	4	1	17	6	2	1	8	2	5	10	2	10	0	2	14	2	2	18	4
300	2	10	0	2	16	3	3	2	6	3	8	9	3	15	0	4	1	3	4	7	6
400	3	6	8	3	15	0	4	3	4	4	11	8	5	0	0	5	8	4	5	16	8
500	4	3	4	4	13	9	5	4	2	5	14	7	6	5	0	6	15	5	7	5	10
600	5	0	0	5	12	6	6	5	0	6	17	6	7	10	0	8	2	6	8	15	0
700	5	16	8	6	11	3	7	5	10	8	0	5	8	15	0	9	9	7	10	4	2
800	6	13	4	7	10	0	8	6	8	9	3	4	10	0	0	10	16	8	11	13	4
900	7	10	0	8	8	9	9	7	6	10	6	3	11	5	0	12	3	9	13	2	6
1000	8	6	8	9	7	6	10	8	4	11	9	2	12	10	0	13	10	10	14	11	8
2000	16	13	4	18	15	0	20	16	8	22	18	4	25	0	0	27	1	8	29	3	4
3000	25	0	0	28	2	6	31	5	0	34	7	6	37	10	0	40	12	6	43	15	0
4000	33	6	8	37	10	0	41	13	4	45	16	8	50	0	0	54	3	4	58	6	8
5000	41	13	4	46	17	6	52	1	8	57	5	10	62	10	0	67	14	2	72	18	4
6000	50	0	0	56	5	0	62	10	0	68	15	0	75	0	0	81	5	0	87	10	0
7000	58	6	8	65	12	6	72	18	4	80	4	2	87	10	0	94	15	10	102	1	8
8000	66	13	4	75	0	0	83	6	8	91	13	4	100	0	0	108	6	8	116	13	4
9000	75	0	0	84	7	6	93	15	0	103	2	6	112	10	0	121	17	6	131	5	0

MONEY TABLE—CONTINUED.

S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
3¾d.		at 4d.			at 4¼d.			at 4½d.			at 4¾d.			at 5d.			at 5¼d.		
0	7½	0	0	8	0	0	8½	0	0	9	0	0	9½	0	0	10	0	0	10½
0	11¼	0	1	0	0	1	0¾	0	1	1½	0	1	2¼	0	1	3	0	1	3¾
1	3	0	1	4	0	1	5	0	1	6	0	1	7	0	1	8	0	1	9
1	6¾	0	1	8	0	1	9¼	0	1	10½	0	1	11¾	0	2	1	0	2	2¼
1	10½	0	2	0	0	2	1½	0	2	3	0	2	4½	0	2	6	0	2	7½
2	2¼	0	2	4	0	2	5¾	0	2	7½	0	2	9¼	0	2	11	0	3	0¾
2	6	0	2	8	0	2	10	0	3	0	0	3	2	0	3	4	0	3	6
2	9¾	0	3	0	0	3	2¼	0	3	4½	0	3	6¾	0	3	9	0	3	11¼
3	1½	0	3	4	0	3	6½	0	3	9	0	3	11½	0	4	2	0	4	4½
3	5¼	0	3	8	0	3	10¾	0	4	1½	0	4	4¼	0	4	7	0	4	9¾
3	9	0	4	0	0	4	3	0	4	6	0	4	9	0	5	0	0	5	3
4	0¾	0	4	4	0	4	7¼	0	4	10½	0	5	1¾	0	5	5	0	5	8¼
4	4½	0	4	8	0	4	11½	0	5	3	0	5	6½	0	5	10	0	6	1½
4	8¼	0	5	0	0	5	3¾	0	5	7½	0	5	11¼	0	6	3	0	6	6¾
5	0	0	5	4	0	5	8	0	6	0	0	6	4	0	6	8	0	7	0
5	3¾	0	5	8	0	6	0¼	0	6	4½	0	6	8¾	0	7	1	0	7	5¼
5	7½	0	6	0	0	6	4½	0	6	9	0	7	1½	0	7	6	0	7	10½
5	11¼	0	6	4	0	6	8¾	0	7	1½	0	7	6¼	0	7	11	0	8	3¾
6	3	0	6	8	0	7	1	0	7	6	0	7	11	0	8	4	0	8	9
9	4½	0	10	0	0	10	7½	0	11	3	0	11	10½	0	12	6	0	13	1½
12	6	0	13	4	0	14	2	0	15	0	0	15	10	0	16	8	0	17	6
15	7½	0	16	8	0	17	8½	0	18	9	0	19	9½	1	0	10	1	1	10½
18	9	1	0	0	1	1	3	1	2	6	1	3	9	1	5	0	1	6	3
1	10½	1	3	4	1	4	9½	1	6	3	1	7	8½	1	9	2	1	10	7½
5	0	1	6	8	1	8	4	1	10	0	1	11	8	1	13	4	1	15	0
8	1½	1	10	0	1	11	10½	1	13	9	1	15	7½	1	17	6	1	19	4½
11	3	1	13	4	1	15	5	1	17	6	1	19	7	2	1	8	2	3	9
2	6	3	6	8	3	10	10	3	15	0	3	19	2	4	3	4	4	7	6
13	9	5	0	0	5	6	3	5	12	6	5	18	9	6	5	0	6	11	3
5	0	6	13	4	7	1	8	7	10	0	7	18	4	8	6	8	8	15	0
16	3	8	6	8	8	17	1	9	7	6	9	17	11	10	8	4	10	18	9
7	6	10	0	0	10	12	6	11	5	0	11	17	6	12	10	0	13	2	6
18	9	11	13	4	12	7	11	13	2	6	13	17	1	14	11	8	15	6	3
10	0	13	6	8	14	3	4	15	0	0	15	16	8	16	13	4	17	10	0
1	3	15	0	0	15	18	9	16	17	6	17	16	3	18	15	0	19	13	9
12	6	16	13	4	17	14	2	18	15	0	19	15	10	20	16	8	21	17	6
5	0	33	6	8	35	8	4	37	10	0	39	11	8	41	13	4	43	15	0
17	6	50	0	0	53	2	6	56	5	0	59	7	6	62	10	0	65	12	6
10	0	66	13	4	70	16	8	75	0	0	79	3	4	83	6	8	87	10	0
2	6	83	6	8	88	10	10	93	15	0	98	19	2	104	3	4	109	7	6
15	0	100	0	0	106	5	0	112	10	0	118	15	0	125	0	0	131	5	0
7	6	116	13	4	123	19	2	131	5	0	138	10	10	145	16	8	153	2	6
0	0	133	6	8	141	13	4	150	0	0	158	6	8	166	13	4	175	0	0
12	6	150	0	0	159	7	6	168	15	0	178	2	6	187	10	0	196	17	6

MONEY TABLE—CONTINUED.

	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
No.	at 5½d.			at 5¾d.			at 6d.			at 6¼d.			at 6½d.			at 6¾d.			at 7d.		
2	0	0	11	0	0	11½	0	1	0	0	1	0½	0	1	1	0	1	1½	0	1	2
3	0	1	4½	0	1	5¼	0	1	6	0	1	6¾	0	1	7½	0	1	8¼	0	1	9
4	0	1	10	0	1	11	0	2	0	0	2	1	0	2	2	0	2	3	0	2	4
5	0	2	3½	0	2	4¾	0	2	6	0	2	7¼	0	2	8½	0	2	9¾	0	2	11
6	0	2	9	0	2	10½	0	3	0	0	3	1½	0	3	3	0	3	4½	0	3	6
7	0	3	2½	0	3	4¼	0	3	6	0	3	7¾	0	3	9½	0	3	11¼	0	4	1
8	0	3	8	0	3	10	0	4	0	0	4	2	0	4	4	0	4	6	0	4	8
9	0	4	1½	0	4	3¾	0	4	6	0	4	8¼	0	4	10½	0	5	0¾	0	5	3
10	0	4	7	0	4	9½	0	5	0	0	5	2½	0	5	5	0	5	7½	0	5	10
11	0	5	0½	0	5	3¼	0	5	6	0	5	8¾	0	5	11½	0	6	2¼	0	6	5
12	0	5	6	0	5	9	0	6	0	0	6	3	0	6	6	0	6	9	0	7	
13	0	5	11½	0	6	2¾	0	6	6	0	6	9¼	0	7	0½	0	7	3¾	0	7	
14	0	6	5	0	6	8½	0	7	0	0	7	3½	0	7	7	0	7	10½	0	8	
15	0	6	10½	0	7	2¼	0	7	6	0	7	9¾	0	8	1½	0	8	5¼	0	8	
16	0	7	4	0	7	8	0	8	0	0	8	4	0	8	8	0	9	0	0	9	
17	0	7	9½	0	8	1¾	0	8	6	0	8	10¼	0	9	2½	0	9	6¾	0	9	
18	0	8	3	0	8	7½	0	9	0	0	9	4½	0	9	9	0	10	1½	0	10	
19	0	8	8½	0	9	1¼	0	9	6	0	9	10¾	0	10	3½	0	10	8¼	0	11	
20	0	9	2	0	9	7	0	10	0	0	10	5	0	10	10	0	11	3	0	11	
30	0	13	9	0	14	4½	0	15	0	0	15	7½	0	16	3	0	16	10½	0	17	
40	0	18	4	0	19	2	1	0	0	1	0	10	1	1	8	1	2	6	1	3	
50	1	2	11	1	3	11½	1	5	0	1	6	0½	1	7	1	1	8	1½	1	9	
60	1	7	6	1	8	9	1	10	0	1	11	3	1	12	6	1	13	9	1	15	
70	1	12	1	1	13	6½	1	15	0	1	16	5½	1	17	11	1	19	4½	2	0	
80	1	16	8	1	18	4	2	0	0	2	1	8	2	3	4	2	5	0	2	6	
90	2	1	3	2	3	1½	2	5	0	2	6	10½	2	8	9	2	10	7½	2	12	
100	2	5	10	2	7	11	2	10	0	2	12	1	2	14	2	2	16	3	2	18	
200	4	11	8	4	15	10	5	0	0	5	4	2	5	8	4	5	12	6	5	16	
300	6	17	6	7	3	9	7	10	0	7	16	3	8	2	6	8	8	9	8	15	
400	9	3	4	9	11	8	10	0	0	10	8	4	10	16	8	11	5	0	11	13	
500	11	9	2	11	19	7	12	10	0	13	0	5	13	10	10	14	1	3	14	11	
600	13	15	0	14	7	6	15	0	0	15	12	6	16	5	0	16	17	6	17	10	
700	16	0	10	16	15	5	17	10	0	18	4	7	18	19	2	19	13	9	20	8	
800	18	6	8	19	3	4	20	0	0	20	16	8	21	13	4	22	10	0	23	6	
900	20	12	6	21	11	3	22	10	0	23	8	9	24	7	6	25	6	3	26	5	
1000	22	18	4	23	19	2	25	0	0	26	0	10	27	1	8	28	2	6	29	3	
2000	45	16	8	47	18	4	50	0	0	52	1	8	54	3	4	56	5	0	58	6	
3000	68	15	0	71	17	6	75	0	0	78	2	6	81	5	0	84	7	6	87	10	
4000	91	13	4	95	16	8	100	0	0	104	3	4	108	6	8	112	10	0	116	13	
5000	114	11	8	119	15	10	125	0	0	130	4	2	135	8	4	140	12	6	145	16	
6000	137	10	0	143	15	0	150	0	0	156	5	0	162	10	0	168	15	0	175	0	
7000	160	8	4	167	14	2	175	0	0	182	5	10	189	11	8	196	17	6	204	3	
8000	183	6	8	191	13	4	200	0	0	208	6	8	216	13	4	225	0	0	233	6	
9000	206	5	0	215	12	6	225	0	0	234	7	6	243	15	0	253	2	6	262	10	

MONEY TABLE—CONTINUED.

	L.	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*
	at 7¼*d.*			at 7½*d.*			at 7¾*d.*			at 8*d.*			at 8¼*d.*			at 8½*d.*			at 8¾*d.*		
2	0	1	2½	0	1	3	0	1	3½	0	1	4	0	1	4½	0	1	5	0	1	5½
3	0	1	9¾	0	1	10½	0	1	11¼	0	2	0	0	2	0¾	0	2	1½	0	2	2¼
4	0	2	5	0	2	6	0	2	7	0	2	8	0	2	9	0	2	10	0	2	11
5	0	3	0¼	0	3	1½	0	3	2¾	0	3	4	0	3	5¼	0	3	6½	0	3	7¾
6	0	3	7½	0	3	9	0	3	10½	0	4	0	0	4	1½	0	4	3	0	4	4½
7	0	4	2¾	0	4	4½	0	4	6¼	0	4	8	0	4	9¾	0	4	11½	0	5	1¼
8	0	4	10	0	5	0	0	5	2	0	5	4	0	5	6	0	5	8	0	5	10
9	0	5	5¼	0	5	7½	0	5	9¾	0	6	0	0	6	2¼	0	6	4½	0	6	6¾
	0	6	0½	0	6	3	0	6	5½	0	6	8	0	6	10½	0	7	1	0	7	3½
	0	6	7¾	0	6	10½	0	7	1¼	0	7	4	0	7	6¾	0	7	9½	0	8	0¼
	0	7	3	0	7	6	0	7	9	0	8	0	0	8	3	0	8	6	0	8	9
	0	7	10¼	0	8	1½	0	8	4¾	0	8	8	0	8	11¼	0	9	2½	0	9	5¾
	0	8	5½	0	8	9	0	9	0½	0	9	4	0	9	7½	0	9	11	0	10	2½
	0	9	0¾	0	9	4½	0	9	8¼	0	10	0	0	10	3¾	0	10	7½	0	10	11¼
	0	9	8	0	10	0	0	10	4	0	10	8	0	11	0	0	11	4	0	11	8
	0	10	3¼	0	10	7½	0	10	11¾	0	11	4	0	11	8¼	0	12	0½	0	12	4¾
	0	10	10½	0	11	3	0	11	7½	0	12	0	0	12	4½	0	12	9	0	13	1½
	0	11	5¾	0	11	10½	0	12	3¼	0	12	8	0	13	0¾	0	13	5½	0	13	10¼
	0	12	1	0	12	6	0	12	11	0	13	4	0	13	9	0	14	2	0	14	7
	0	18	1½	0	18	9	0	19	4½	1	0	0	1	0	7½	1	1	3	1	1	10½
	1	4	2	1	5	0	1	5	10	1	6	8	1	7	6	1	8	4	1	9	2
	1	10	2½	1	11	3	1	12	3½	1	13	4	1	14	4½	1	15	5	1	16	5½
	1	16	3	1	17	6	1	18	9	2	0	0	2	1	3	2	2	6	2	3	9
	2	2	3½	2	3	9	2	5	2½	2	6	8	2	8	1½	2	9	7	2	11	0½
	2	8	4	2	10	0	2	11	8	2	13	4	2	15	0	2	16	8	2	18	4
	2	14	4½	2	16	3	2	18	1½	3	0	0	3	1	10½	3	3	9	3	5	7½
	3	0	5	3	2	6	3	4	7	3	6	8	3	8	9	3	10	10	3	12	11
	6	0	10	6	5	0	6	9	2	6	13	4	6	17	6	7	1	8	7	5	10
	9	1	3	9	7	6	9	13	9	10	0	0	10	6	3	10	12	6	10	18	9
	12	1	8	12	10	0	12	18	4	13	6	8	13	15	0	14	3	4	14	11	8
	15	2	1	15	12	6	16	2	11	16	13	4	17	3	9	17	14	2	18	4	7
	18	2	6	18	15	0	19	7	6	20	0	0	20	12	6	21	5	0	21	17	6
	21	2	11	21	17	6	22	12	1	23	6	8	24	1	3	24	15	10	25	10	5
	24	3	4	25	0	0	25	16	8	26	13	4	27	10	0	28	6	8	29	3	4
	27	3	9	28	2	6	29	1	3	30	0	0	30	18	9	31	17	6	32	16	3
	30	4	2	31	5	0	32	5	10	33	6	8	34	7	6	35	8	4	36	9	2
	60	8	4	62	10	0	64	11	8	66	13	4	68	15	0	70	16	8	72	18	4
	90	12	6	93	15	0	96	17	6	100	0	0	103	2	6	106	5	0	109	7	6
	120	16	8	125	0	0	129	3	4	133	6	8	137	10	0	141	13	4	145	16	8
	151	0	10	156	5	0	161	9	2	166	13	4	171	17	6	177	1	8	182	5	10
	181	5	0	187	10	0	193	15	0	200	0	0	206	5	0	212	10	0	218	15	0
	211	9	2	218	15	0	226	0	10	233	6	8	240	12	6	247	18	4	255	4	2
	241	13	4	250	0	0	258	6	8	266	13	4	275	0	0	283	6	8	291	13	4
	271	17	6	281	5	0	290	12	6	300	0	0	309	7	6	318	15	0	328	2	6

MONEY TABLE—CONTINUED.

	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.
No.	at 9*d.*			at 9¼*d.*			at 9½*d.*			at 9¾*d.*			at 10*d.*			at 10¼*d.*			at 10½*d.*	
2	0	1	6	0	1	6½	0	1	7	0	1	7½	0	1	8	0	1	8½	0	1
3	0	2	3	0	2	3¾	0	2	4½	0	2	5¼	0	2	6	0	2	6¾	0	2
4	0	3	0	0	3	1	0	3	2	0	3	3	0	3	4	0	3	5	0	3
5	0	3	9	0	3	10¼	0	3	11½	0	4	0¾	0	4	2	0	4	3¼	0	4
6	0	4	6	0	4	7½	0	4	9	0	4	10½	0	5	0	0	5	1½	0	5
7	0	5	3	0	5	4¾	0	5	6½	0	5	8¼	0	5	10	0	5	11¾	0	6
8	0	6	0	0	6	2	0	6	4	0	6	6	0	6	8	0	6	10	0	7
9	0	6	9	0	6	11¼	0	7	1½	0	7	3¾	0	7	6	0	7	8¼	0	7
10	0	7	6	0	7	8½	0	7	11	0	8	1½	0	8	4	0	8	6½	0	8
11	0	8	3	0	8	5¾	0	8	8½	0	8	11¼	0	9	2	0	9	4¾	0	9
12	0	9	0	0	9	3	0	9	6	0	9	9	0	10	0	0	10	3	0	10
13	0	9	9	0	10	0¼	0	10	3½	0	10	6¾	0	10	10	0	11	1¼	0	11
14	0	10	6	0	10	9½	0	11	1	0	11	4½	0	11	8	0	11	11½	0	12
15	0	11	3	0	11	6¾	0	11	10½	0	12	2¼	0	12	6	0	12	9¾	0	13
16	0	12	0	0	12	4	0	12	8	0	13	0	0	13	4	0	13	8	0	14
17	0	12	9	0	13	1¼	0	13	5½	0	13	9¾	0	14	2	0	14	6¼	0	14
18	0	13	6	0	13	10½	0	14	3	0	14	7½	0	15	0	0	15	4½	0	15
19	0	14	3	0	14	7¾	0	15	0½	0	15	5¼	0	15	10	0	16	2¾	0	16
20	0	15	0	0	15	5	0	15	10	0	16	3	0	16	8	0	17	1	0	17
30	1	2	6	1	3	1½	1	3	9	1	4	4½	1	5	0	1	5	7½	1	6
40	1	10	0	1	10	10	1	11	8	1	12	6	1	13	4	1	14	2	1	15
50	1	17	6	1	18	6½	1	19	7	2	0	7½	2	1	8	2	2	8½	2	3
60	2	5	0	2	6	3	2	7	6	2	8	9	2	10	0	2	11	3	2	12
70	2	12	6	2	13	11½	2	15	5	2	16	10½	2	18	4	2	19	9½	3	1
80	3	0	0	3	1	8	3	3	4	3	5	0	3	6	8	3	8	4	3	10
90	3	7	6	3	9	4½	3	11	3	3	13	1½	3	15	0	3	16	10½	3	18
100	3	15	0	3	17	1	3	19	2	4	1	3	4	3	4	4	5	5	4	7
200	7	10	0	7	14	2	7	18	4	8	2	6	8	6	8	8	10	10	8	15
300	11	5	0	11	11	3	11	17	6	12	3	9	12	10	0	12	16	3	13	2
400	15	0	0	15	8	4	15	16	8	16	5	0	16	13	4	17	1	8	17	10
500	18	15	0	19	5	5	19	15	10	20	6	3	20	16	8	21	7	1	21	17
600	22	10	0	23	2	6	23	15	0	24	7	6	25	0	0	25	12	6	26	5
700	26	5	0	26	19	7	27	14	2	28	8	9	29	3	4	29	17	11	30	12
800	30	0	0	30	16	8	31	13	4	32	10	0	33	6	8	34	3	4	35	0
900	33	15	0	34	13	9	35	12	6	36	11	3	37	10	0	38	8	9	39	7
1000	37	10	0	38	10	10	39	11	8	40	12	6	41	13	4	42	14	2	43	15
2000	75	0	0	77	1	8	79	3	4	81	5	0	83	6	8	85	8	4	87	10
3000	112	10	0	115	12	6	118	15	0	121	17	6	125	0	0	128	2	6	131	5
4000	150	0	0	154	3	4	158	6	8	162	10	0	166	13	4	170	16	8	175	0
5000	187	10	0	192	14	2	197	18	4	203	2	6	208	6	8	213	10	10	218	15
6000	225	0	0	231	5	0	237	10	0	243	15	0	250	0	0	256	5	0	262	10
7000	262	10	0	269	15	10	277	1	8	284	7	6	291	13	4	298	19	2	306	5
8000	300	0	0	308	6	8	316	13	4	325	0	0	333	6	8	341	13	4	350	0
9000	337	10	0	346	17	6	356	5	0	365	12	6	375	0	0	384	7	6	393	15

MONEY TABLE—CONTINUED.

	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
No.	at 10¾d.			at 11d.			at 11¼d.			at 11½d.			at 11¾d.			at 1s.		
2	0	1	9½	0	1	10	0	1	10½	0	1	11	0	1	11½	0	2	0
3	0	2	8¼	0	2	9	0	2	9¾	0	2	10½	0	2	11¼	0	3	0
4	0	3	7	0	3	8	0	3	9	0	3	10	0	3	11	0	4	0
5	0	4	5¾	0	4	7	0	4	8¼	0	4	9½	0	4	10¾	0	5	0
6	0	5	4½	0	5	6	0	5	7½	0	5	9	0	5	10½	0	6	0
7	0	6	3¼	0	6	5	0	6	6¾	0	6	8½	0	6	10¼	0	7	0
8	0	7	2	0	7	4	0	7	6	0	7	8	0	7	10	0	8	0
9	0	8	0¾	0	8	3	0	8	5¼	0	8	7½	0	8	9¾	0	9	0
10	0	8	11½	0	9	2	0	9	4½	0	9	7	0	9	9½	0	10	0
11	0	9	10¼	0	10	1	0	10	3¾	0	10	6½	0	10	9¼	0	11	0
12	0	10	9	0	11	0	0	11	3	0	11	6	0	11	9	0	12	0
13	0	11	7¾	0	11	11	0	12	2¼	0	12	5½	0	12	8¾	0	13	0
14	0	12	6½	0	12	10	0	13	1½	0	13	5	0	13	8½	0	14	0
15	0	13	5¼	0	13	9	0	14	0¾	0	14	4½	0	14	8¼	0	15	0
16	0	14	4	0	14	8	0	15	0	0	15	4	0	15	8	0	16	0
17	0	15	2¾	0	15	7	0	15	11¼	0	16	3½	0	16	7¾	0	17	0
18	0	16	1½	0	16	6	0	16	10½	0	17	3	0	17	7½	0	18	0
19	0	17	0¼	0	17	5	0	17	9¾	0	18	2½	0	18	7¼	0	19	0
20	0	17	11	0	18	4	0	18	9	0	19	2	0	19	7	1	0	0
30	1	6	10½	1	7	6	1	8	1½	1	8	9	1	9	4½	1	10	0
40	1	15	10	1	16	8	1	17	6	1	18	4	1	19	2	2	0	0
50	2	4	9½	2	5	10	2	6	10½	2	7	11	2	8	11½	2	10	0
60	2	13	9	2	15	0	2	16	3	2	17	6	2	18	9	3	0	0
70	3	2	8½	3	4	2	3	5	7½	3	7	1	3	8	6½	3	10	0
80	3	11	8	3	13	4	3	15	0	3	16	8	3	18	4	4	0	0
90	4	0	7½	4	2	6	4	4	4½	4	6	3	4	8	1½	4	10	0
100	4	9	7	4	11	8	4	13	9	4	15	10	4	17	11	5	0	0
200	8	19	2	9	3	4	9	7	6	9	11	8	9	15	10	10	0	0
300	13	8	9	13	15	0	14	1	3	14	7	6	14	13	9	15	0	0
400	17	18	4	18	6	8	18	15	0	19	3	4	19	11	8	20	0	0
500	22	7	11	22	18	4	23	8	9	23	19	2	24	9	7	25	0	0
600	26	17	6	27	10	0	28	2	6	28	15	0	29	7	6	30	0	0
700	31	7	1	32	1	8	32	16	3	33	10	10	34	5	5	35	0	0
800	35	16	8	36	13	4	37	10	0	38	6	8	39	3	4	40	0	0
900	40	6	3	41	5	0	42	3	9	43	2	6	44	1	3	45	0	0
1000	44	15	10	45	16	8	46	17	6	47	18	4	48	19	2	50	0	0
2000	89	11	8	91	13	4	93	15	0	95	16	8	97	18	4	100	0	0
3000	134	7	6	137	10	0	140	12	6	143	15	0	146	17	6	150	0	0
4000	179	3	4	183	6	8	187	10	0	191	13	4	195	16	8	200	0	0
5000	223	19	2	229	3	4	234	7	6	239	11	8	244	15	10	250	0	0
6000	268	15	0	275	0	0	281	5	0	287	10	0	293	15	0	300	0	0
7000	313	10	10	320	16	8	328	2	6	335	8	4	342	14	2	350	0	0
8000	358	6	8	366	13	4	375	0	0	383	6	8	391	13	4	400	0	0
9000	403	2	6	412	10	0	421	17	6	431	5	0	440	12	6	450	0	0

·EQUIVALENT PRICES TO COMMON WEIGHTS AND NUMBERS.

Per ton or 2240 lbs.			cwt. or 112 lbs.			qr. or 28 lbs.			stone or 14 lbs.		lb. or 1.	doz. or 12.		score or 20.		per 100.			per 120.			gross or 144.			per 1000.		
L.	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*S.*	*D.*	*D.*	*S.*	*D.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*	*L.*	*S.*	*D.*
2	6	8	0	2	4	0	0	7	0	3½	¼	0	3	0	5	0	2	1	0	2	6	0	3	0	1	0	10
3	10	0	0	3	6	0	0	10½	0	5¼	⅜	0	4½	0	7½	0	3	1½	0	3	9	0	4	6	1	11	3
4	13	4	0	4	8	0	1	2	0	7	½	0	6	0	10	0	4	2	0	5	0	0	6	0	2	1	8
5	16	8	0	5	10	0	1	5½	0	8¾	⅝	0	7½	1	0½	0	5	2½	0	6	3	0	7	6	2	12	1
7	0	0	0	7	0	0	1	9	0	10½	¾	0	9	1	3	0	6	3	0	7	6	0	9	0	3	2	6
8	3	4	0	8	2	0	2	0½	1	0¼	⅞	0	10½	1	5½	0	7	3½	0	8	9	0	10	6	3	12	11
9	6	8	0	9	4	0	2	4	1	2	1*d.*	1	0	1	8	0	8	4	0	10	0	0	12	0	4	3	4
10	10	0	0	10	6	0	2	7½	1	3¾	1⅛	1	1½	1	10½	0	9	4½	0	11	3	0	13	6	4	13	9
11	13	4	0	11	8	0	2	11	1	5½	1¼	1	3	2	1	0	10	5	0	12	6	0	15	0	5	4	2
12	16	8	0	12	10	0	3	2½	1	7¼	1⅜	1	4½	2	3½	0	11	5½	0	13	9	0	16	6	5	14	7
14	0	0	0	14	0	0	3	6	1	9	1½	1	6	2	6	0	12	6	0	15	0	0	18	0	6	5	0
15	3	4	0	15	2	0	3	9½	1	10¾	1⅝	1	7½	2	8½	0	13	6½	0	16	3	0	19	6	6	15	5
16	6	8	0	16	4	0	4	1	2	0½	1¾	1	9	2	11	0	14	7	0	17	6	1	1	0	7	5	10
17	10	0	0	17	6	0	4	4½	2	2¼	1⅞	1	10½	3	1½	0	15	7½	0	18	9	1	2	6	7	16	3
18	13	4	0	18	8	0	4	8	2	4	2*d.*	2	0	3	4	0	16	8	1	0	0	1	4	0	8	6	8
19	16	8	0	19	10	0	4	11½	2	5¾	2⅛	2	1½	3	6½	0	17	8½	1	1	3	1	5	6	8	17	1
21	0	0	1	1	0	0	5	3	2	7½	2¼	2	3	3	9	0	18	9	1	2	6	1	7	0	9	7	6
22	3	4	1	2	2	0	5	6½	2	9¼	2⅜	2	4½	3	11½	0	19	9½	1	3	9	1	8	6	9	17	11
23	6	8	1	3	4	0	5	10	2	11	2½	2	6	4	2	1	0	10	1	5	0	1	10	0	10	8	4
24	10	0	1	4	6	0	6	1½	3	0¾	2⅝	2	7½	4	4½	1	1	10½	1	6	3	1	11	6	10	18	9
25	13	4	1	5	8	0	6	5	3	2½	2¾	2	9	4	7	1	2	11	1	7	6	1	13	0	11	9	2
26	16	8	1	6	10	0	6	8½	3	4¼	2⅞	2	10½	4	9½	1	3	11½	1	8	9	1	14	6	11	19	7
28	0	0	1	8	0	0	7	0	3	6	3*d.*	3	0	5	0	1	5	0	1	10	0	1	16	0	12	10	0
29	3	4	1	9	2	0	7	3½	3	7¼	3⅛	3	1½	5	2½	1	6	0½	1	11	3	1	17	6	13	0	5
30	6	8	1	10	4	0	7	7	3	9½	3¼	3	3	5	5	1	7	1	1	12	6	1	19	0	13	10	10
31	10	0	1	11	6	0	7	10½	3	11¼	3⅜	3	4½	5	7½	1	8	1½	1	13	9	2	0	6	14	1	3
32	13	4	1	12	8	0	8	2	4	1	3½	3	6	5	10	1	9	2	1	15	0	2	2	0	14	11	8
33	16	8	1	13	4	0	8	5½	4	2¾	3⅝	3	7½	6	0½	1	10	2½	1	16	3	2	3	6	15	2	1
35	0	0	1	15	0	0	8	9	4	4½	3¾	3	9	6	3	1	11	3	1	17	6	2	5	0	15	12	6
36	3	4	1	16	2	0	9	0½	4	6¼	3⅞	3	10½	6	5½	1	12	3½	1	18	9	2	6	6	16	2	11
37	6	8	1	17	4	0	9	4	4	8	4*d.*	4	0	6	8	1	13	4	2	0	0	2	8	0	16	13	4

38 10 0	1 18 6	0 9 7½	4 9¾	4⅛	4 1½	6 10½	1 14 4½	2 1 3	2 9 6	17 3 9
39 13 4	1 19 8	0 9 11	4 11½	4¼	4 3	7 1	1 15 5	2 2 6	2 11 0	17 14 2
40 16 8	2 0 10	0 10 2½	5 1¼	4⅜	4 4½	7 3½	1 16 5½	2 3 9	2 12 6	18 4 7
42 0 0	2 2 0	0 10 6	5 3	4½	4 6	7 6	1 17 6	2 5 0	2 14 0	18 15 0
43 3 4	2 3 2	0 10 9½	5 4¾	4⅝	4 7½	7 8½	1 18 6½	2 6 3	2 15 6	19 5 5
44 6 8	2 4 4	0 11 1	5 6½	4¾	4 9	7 11	1 19 7	2 7 6	2 17 0	19 15 10
45 10 0	2 5 6	0 11 4½	5 8¼	4⅞	4 10½	8 1½	2 0 7½	2 8 9	2 18 6	20 6 3
46 13 4	2 6 8	0 11 8	5 10	5*d.*	5 0	8 4	2 1 8	2 10 0	3 0 0	20 16 8
49 0 0	2 9 0	0 12 3	6 1½	5¼	5 3	8 9	2 3 9	2 12 6	3 3 0	21 17 6
51 6 8	2 11 4	0 12 10	6 5	5½	5 6	9 2	2 5 10	2 15 0	3 6 0	22 18 4
53 13 4	2 13 8	0 13 5	6 8½	5¾	5 9	9 7	2 7 11	2 17 6	3 9 0	23 19 2
56 0 0	2 16 0	0 14 0	7 0	6*d.*	6 0	10 0	2 10 0	3 0 0	3 12 0	25 0 0
58 6 8	2 18 4	0 14 7	7 3½	6¼	6 3	10 5	2 12 1	3 2 6	3 15 0	26 0 10
60 13 4	3 0 8	0 15 2	7 7	6½	6 6	10 10	2 14 2	3 5 0	3 18 0	27 1 8
63 0 0	3 3 0	0 15 9	7 10½	6¾	6 9	11 3	2 16 3	3 7 6	4 1 0	28 2 6
65 6 8	3 5 4	0 16 4	8 2	7*d.*	7 0	11 8	2 18 4	3 10 0	4 4 0	29 3 4
67 13 4	3 7 8	0 16 11	8 5½	7¼	7 3	12 1	3 0 5	3 12 6	4 7 0	30 4 2
70 0 0	3 10 0	0 17 6	8 9	7½	7 6	12 6	3 2 6	3 15 0	4 10 0	31 5 0
72 6 8	3 12 4	0 18 1	9 0½	7¾	7 9	12 11	3 4 7	3 17 6	4 13 0	32 5 10
74 13 4	3 14 8	0 18 8	9 4	8*d.*	8 0	13 4	3 6 8	4 0 0	4 16 0	33 6 8
77 0 0	3 17 0	0 19 3	9 7½	8¼	8 3	13 9	3 8 9	4 2 6	4 19 0	34 7 6
79 6 8	3 19 4	0 19 10	9 11	8½	8 6	14 2	3 10 10	4 5 0	5 2 0	35 8 4
81 13 4	4 1 8	1 0 5	10 2½	8¾	8 9	14 7	3 12 11	4 7 6	5 5 0	36 9 2
84 0 0	4 4 0	1 1 0	10 6	9*d.*	9 0	15 0	3 15 0	4 10 0	5 8 0	37 10 0
86 6 8	4 6 4	1 1 7	10 9½	9¼	9 3	15 5	3 17 1	4 12 6	5 11 0	38 10 10
88 13 4	4 8 8	1 2 2	11 1	9½	9 6	15 10	3 19 2	4 15 0	5 14 0	39 11 8
91 0 0	4 11 0	1 2 9	11 4½	9¾	9 9	16 3	4 1 3	4 17 6	5 17 0	40 12 6
93 6 8	4 13 4	1 3 4	11 8	10*d.*	10 0	16 8	4 3 4	5 0 0	6 0 0	41 13 4
95 13 4	4 15 8	1 3 11	11 11½	10¼	10 3	17 1	4 5 5	5 2 6	6 3 0	42 14 2
98 0 0	4 18 0	1 4 6	12 3	10½	10 6	17 6	4 7 6	5 5 0	6 6 0	43 15 0
100 6 8	5 0 4	1 5 1	12 6½	10¾	10 9	17 11	4 9 7	5 7 6	6 9 0	44 15 10
102 13 4	5 2 8	1 5 8	12 10	11*d.*	11 0	18 4	4 11 8	5 10 0	6 12 0	45 16 8
105 0 0	5 5 0	1 6 3	13 1½	11¼	11 3	18 9	4 13 9	5 12 6	6 15 0	46 17 6
107 6 8	5 7 4	1 6 10	13 5	11½	11 6	19 2	4 15 10	5 15 0	6 18 0	47 18 4
109 13 4	5 9 8	1 7 5	13 8½	11¾	11 9	19 7	4 17 11	5 17 6	7 1 0	48 19 2
112 0 0	5 12 0	1 8 0	14 0	12*d.*	12 0	20 0	5 0 0	6 0 0	7 4 0	50 0 0

Practical Utility of the Preceding Tables.

1. What will be the cost of 1 ton 2 cwts. 3qrs. 4 lbs. at 7¾*d.* per lb.

1 ton = 2240 lbs.
2 cwts. = 224 „
3 qrs. = 84 „
4 lbs. = 4 „
Total = 2552 „

And 2000 at 7¾*d.* (as per Table, p. 131)	=£64	11	8
500 „	= 16	2	11
50 „	= 1	12	3½
2 „	= 0	1	3½
2552	£82	8	2

2. In the Table of Equivalent Prices, the fifth column from the left hand is the price per single article, or 1; hence the other columns on the right and left of that give the price at an equal rate, according to the various denominations by which the columns are headed.

Thus, suppose the price per lb.=3¼*d.*, the price per ton=£30. 6*s.* 8*d.* Again, suppose the price per gross =£1. 10*s.*, the price per dozen=2*s.* 6*d.*, &c.

STRENGTH OF MATERIALS.

Materials of construction are liable to four different kinds of strain; viz., stretching, crushing, transverse action, and torsion or twisting: the first of which depends upon the body's tenacity alone; the second, on its resistance to compression; the third, on its tenacity and compression combined; and the fourth, on that property by which it opposes any acting force tending to change from a straight line, to that of a spiral direction, the fibres of which the body is composed.

In bodies, the power of tenacity and resistance to compression in the direction of their length, is as the cross section of their area multiplied by the results of experiments on similar bodies, as exhibited in the following Table.

Table showing the Tenacities, Resistances to Compression, and other Properties of the common Materials of Construction.

Names of Bodies.	Absolute		Compared with Cast Iron		
	Tenacity in lbs. per sq. inch.	Resistance to compression in lbs. per sq. in.	Its strength is	Its extensibility is	Its stiffness is
Ash	14130	—	0·23	2·6	0·089
Beech	12225	8548	0·15	2·1	0·073
Brass	17968	10304	0·435	0·9	0·49
Brick	275	562	—	—	—
Cast iron	13434	86397	1·000	1·0	1·000
Copper (wrought)	33000	—	—	—	—
Elm	9720	1033	0·21	2·9	0·073
Fir, or Pine, white	12346	2028	0·23	2·4	0·1
„ „ red	11800	5375	0·3	2·4	0·1
„ „ yellow	11835	5445	0·25	2·9	0·087
Granite, Aberdeen	—	10910	—	—	—
Gun-metal (copper 8, and tin 1)	35838	—	0·65	1·25	0·535
Malleable iron	56000	—	1·12	0·86	1·3
Larch	12240	5568	0·136	2·3	0·058
Lead	1824	—	0·096	2·5	0·0385
Mahogany, Honduras	11475	8000	0·24	2·9	0·487
Marble	551	6060	—	—	—
Oak	11880	9504	0·25	2·8	0·093
Rope (1 in. in circum.)	200	—	—	—	—
Steel	128000	—	—	—	—
Stone, Bath	478	—	—	—	—
„ Craigleith	772	5490	—	—	—
„ Dundee	2661	6630	—	—	—
„ Portland	857	3729	—	—	—
Tin (cast)	4736	—	0·182	0·75	0·25
Zinc (sheet)	9120	—	0·365	0·5	0·76

Comparative Strength and Weight of Ropes and Chains.

Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt.		Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt	
$3\frac{1}{2}$	$2\frac{3}{4}$	$\frac{5}{16}$	$5\frac{1}{2}$	1	$5\frac{1}{2}$	10	23	$\frac{7}{8}$	43	10	0
$4\frac{1}{4}$	$4\frac{1}{4}$	$\frac{3}{8}$	8	1	$16\frac{3}{4}$	$10\frac{3}{4}$	28	$\frac{15}{16}$	49	11	11
5	$5\frac{3}{4}$	$\frac{7}{16}$	$10\frac{1}{4}$	2	10	$11\frac{1}{2}$	$30\frac{1}{2}$	1in.	56	13	8
$5\frac{3}{4}$	7	$\frac{1}{2}$	14	3	$5\frac{1}{2}$	$12\frac{1}{4}$	36	$1\frac{1}{16}$	63	14	18
$6\frac{1}{2}$	$9\frac{3}{4}$	$\frac{9}{16}$	18	4	$3\frac{1}{2}$	13	39	$1\frac{1}{8}$	71	16	14
7	$11\frac{1}{4}$	$\frac{5}{8}$	22	5	2	$13\frac{3}{4}$	45	$1\frac{3}{16}$	79	18	11
8	15	$\frac{11}{16}$	27	6	$4\frac{1}{2}$	$14\frac{1}{2}$	$48\frac{1}{2}$	$1\frac{1}{4}$	87	20	8
$8\frac{3}{4}$	19	$\frac{3}{4}$	32	7	7	$15\frac{1}{4}$	56	$1\frac{5}{16}$	96	22	13
$9\frac{1}{2}$	21	$\frac{13}{16}$	37	8	$13\frac{1}{2}$	16	60	$1\frac{3}{8}$	106	24	18

Note.—It must be understood and also borne in mind, that in estimating the amount of tensile strain to which a body is subjected, the weight of the body itself must also be taken into account; for according to its position so may it approximate to its whole weight, in tending to produce tension within itself; as in the almost constant application of ropes and chains to great depths, considerable heights, &c.

Alloys that are of greater Tenacity than the Sum of their Constituents, as determined by the Experiments of Muschenbroek.

Swedish copper 6 parts, Malacca tin 1;	tenacity	per sq. inch	64,000 lbs.
Chili copper 6 parts, Malacca tin 1;	,,	,,	60,000 ,,
Japan copper 5 parts, Banca tin 1;	,,	,,	57,000 ,,
Anglesea copper 6 parts, Cornish tin 1;	,,	,,	41,000 ,,
Common block tin 4, lead 1, zinc 1;	,,	,,	13,000 ,,
Malacca tin 4, regulus of antimony 1;	,,	,,	12,000 ,,
Block tin 3, lead 1;	,,	,,	10,200 ,,
Block tin 8, zinc 1;	,,	,,	10,000 ,,
Lead 1, zinc 1;	,,	,,	4,500 ,,

RESISTANCE TO LATERAL PRESSURE, OR TRANSVERSE ACTION.

The strength of a square or rectangular beam to resist lateral pressure acting in a perpendicular direction to its length, is as the breadth and square of the depth, and inversely as the length;—thus, a beam twice the breadth of another, all other circumstances being alike, equal twice the strength of the other; or twice the depth, equal four times the strength, and twice the length, equal only one half the strength, &c., according to the rule.

Table of Data, containing the results of Experiments on the Elasticity and Strength of various Species of Timber, by Mr. Barlow.

Species of Timber.	Value of E.	Value of S.	Species of Timber.	Value of E.	Value of S.
Teak.........	174·7	2462	Elm	50·64	1013
Poona	122·26	2221	Pitch pine.........	88·68	1632
English oak	105	1672	Red pine	133	1341
Canadian do.	155·5	1766	New England fir	158·5	1102
Dantzic do.	86·2	1457	Riga fir	90	1100
Adriatic do.	70·5	1383	Mar Forest fir ...	63	1200
Ash	119	2026	Larch	76	900
Beech	98	1556	Norway spruce...	105·47	1474

To find the dimensions of a beam capable of sustaining a given weight, with a given degree of deflection, when supported at both ends.

Rule.—Multiply the weight to be supported in ℔s. by the cube of the length in feet; divide the product by 32 times the tabular value of E, multiplied into the given deflection in inches, and th quotient is the breadth multiplied by the cube of the depth in inches.

Note 1.—When the beam is intended to be square, then the fourth root of the quotient is the breadth and depth required.

Note 2.—If the beam is to be cylindrical, multiply the quotient by 1·7, and the fourth root of the product is the diameter.

Ex. The distance between the supports of a beam of Riga fir is 16 feet, and the weight it must be capable of sustaining in the middle of its length is 8000 lbs., with a deflection of not more than $\frac{3}{4}$ of an inch; what must be the depth of the beam, supposing the breadth 8 inches?

$$\frac{16 \times 8000}{90 \times 32 \times \cdot 75} = 15175 \div 8 = \sqrt[3]{1897} = 12{\cdot}35 \text{ inches the depth.}$$

To determine the absolute strength of a rectangular beam of timber when supported at both ends, and loaded in the middle of its length, as beams in general ought to be calculated to, so that they may be rendered capable of withstanding all accidental cases of emergency.

Rule.—Multiply the tabular value of s by four times the depth of the beam in inches, and by the area of the cross section in inches; divide the product by the distance between the supports in inches, and the quotient will be the absolute strength of the beam in lbs.

Note 1.—If the beam be not laid horizontally, the distance between the supports, for calculation, must be the horizontal distance.

Note 2.—One-fourth of the weight obtained by the rule is the greatest weight that ought to be applied in practice as permanent load.

Note 3.—If the load is to be applied at any other point *than the middle*, then the strength will be, as the product of *the two distances* is to the square of half the length of the beam between the supports;—or, twice the distance from one end, multiplied by twice from the other, and divided by the whole length, equal the effective length of the beam.

Ex. In a building 18 feet in width, an engine boiler of $5\frac{1}{2}$ tons is to be fixed, the centre of which to be 7 feet from the wall; and having two pieces of red pine 10 inches by 6, which I can lay across the two walls for the purpose of slinging it at each end,—may I with sufficient confidence apply them, so as to effect this object?

$$\frac{2240 \times 5{\cdot}5}{2} = 6160 \text{ lbs. to carry at each end.}$$

And 18 feet—7=11, double each, or 14 and 22, then

$$\frac{14 \times 22}{18} = 17 \text{ feet, or 204 inches, effective length of beam.}$$

$$\text{Tabular value of s, red pine} = \frac{1341 \times 4 \times 10 \times 60}{204} = 15776 \text{ lbs.,}$$

the absolute strength of each piece of timber at that point.

To determine the dimensions of a rectangular beam capable of supporting a required weight, with a given degree of deflection, when fixed at one end.

Rule.—Divide the weight to be supported, in lbs., by the tabular value of E, multiplied by the breadth and deflection, both in inches; and the cube root of the quotient, multiplied by the length in feet, equal the depth required in inches.

Ex. A beam of ash is intended to bear a load of 700 lbs. at its extremity; its length being 5 feet, its breadth 4 inches, and the deflection not to exceed $\frac{1}{2}$ an inch.

Tabular value of $E = 119 \times 4 \times {\cdot}5 = 238$, the divisor;

then $700 \div 238 = \sqrt[3]{2{\cdot}94} \times 5 = 7{\cdot}25$ inches, depth of the beam.

To find the absolute strength of a rectangular

beam, when fixed at one end, and loaded at the other.

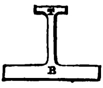
Rule.—Multiply the value of s by the depth of the beam, and by the area of its section, both in inches; divide the product by the leverage in inches, and the quotient equal the absolute strength of the beam in lbs.

Ex. A beam of Riga fir, 12 inches by $4\frac{1}{2}$, and projecting $6\frac{1}{2}$ feet from the wall; what is the greatest weight it will support at the extremity of its length?

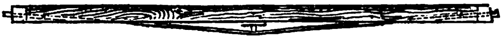
Tabular value of $s=1100$
$12 \times 4{\cdot}5=54$ sectional area.

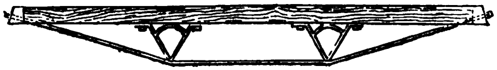
$$\text{Then, } \frac{1100 \times 12 \times 54}{78}=9138{\cdot}4 \text{ lbs.}$$

When fracture of a beam is produced by vertical pressure, the fibres of the lower section of fracture are separated by extension, whilst at the same time those of the upper portion are destroyed by compression; hence exists a point in section where neither the one nor the other takes place, and which is distinguished as the point of neutral axis. Therefore, by the law of fracture thus established, and proper data of tenacity and compression given, as in the Table (p. 137), we are enabled to form metal beams of strongest section with the least possible material: thus, in cast iron the resistance to compression is nearly as $6\frac{1}{2}$ to 1 of tenacity; consequently a beam of cast iron to be of strongest section must be of the following form, and a parabola in the direction of its length, the quantity of material in the bottom flange being about $6\frac{1}{2}$ times that of the upper: but such is not the case with beams of timber; for although the tenacity of *timber be on* an average twice that of its resistance to *compression,* its flexibility is so great, that any con-



siderable length of beam, where columns cannot be situated to its support, requires to be strengthened or trussed by iron rods, as in the following manner:





And these applications of principle not only tend to diminish deflection, but the required purpose is also more effectively attained, and that by lighter pieces of timber.

To ascertain the absolute strength of a cast-iron beam of the preceding form, or that of strongest section.

Rule.—Multiply the sectional area of the bottom flange in inches by the depth of the beam in inches, and divide the product by the distance between the supports also in inches; and 514 times the quotient equal the absolute strength of the beam in cwts.

The strongest form in which any given quantity of matter can be disposed is that of a hollow cylinder; and it has been demonstrated that the maximum of strength is obtained in cast iron when the thickness of the annulus or ring amounts to $\frac{1}{5}$th of the cylinder's external diameter; the relative strength of a solid to that of a hollow cylinder being as the diameters of their sections.

A Table showing the Weight or Pressure a Beam of Cast Iron, 1 inch in breadth, will sustain without destroying its elastic force, when it is supported at each end, and loaded in the middle of its length, and also the deflection in the middle which that weight will produce. By Mr. Hodgkinson, Manchester.

Length.	6 feet.		7 feet.		8 feet.		9 feet.		10 feet.	
Depth in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.
3	1278	·24	1089	·33	954	·426	855	·54	765	·66
3½	1739	·205	1482	·28	1298	·365	1164	·46	1041	·57
4	2272	·18	1936	·245	1700	·32	1520	·405	1360	·5
4½	2875	·16	2450	·217	2146	·284	1924	·36	1721	·443
5	3560	·144	3050	·196	2650	·256	2375	·32	2125	·4
6	5112	·12	4356	·163	3816	·213	3420	·27	3060	·33
7	6958	·103	5929	·14	5194	·183	4655	·23	4165	·29
8	9088	·09	7744	·123	6784	·16	6080	·203	5440	·25
9	—	—	9801	·109	8586	·142	7695	·18	6885	·22
10	—	—	12100	·098	10600	·128	9500	·162	8500	·2
11	—	—	—	—	12826	·117	11495	·15	10285	·182
12	—	—	—	—	15264	·107	13680	·135	12240	·17
13	—	—	—	—	—	—	16100	·125	14400	·154
14	—	—	—	—	—	—	18600	·115	16700	·143
	12 feet.		14 feet.		16 feet.		18 feet.		20 feet.	
6	2548	·48	2184	·65	1912	·85	1699	1·08	1530	1·34
7	3471	·41	2975	·58	2603	·73	2314	·93	2082	1·14
8	4532	·36	3884	·49	3396	·64	3020	·81	2720	1·00
9	5733	·32	4914	·44	4302	·57	3825	·72	3438	·89
10	7083	·28	6071	·39	5312	·51	4722	·64	4250	·8
11	8570	·26	7346	·36	6428	·47	5714	·59	5142	·73
12	10192	·24	8736	·33	7648	·43	6796	·54	6120	·67
13	11971	·22	10260	·31	8978	·39	7980	·49	7182	·61
14	13883	·21	11900	·28	10412	·36	9255	·46	8330	·57
15	15937	·19	13660	·26	11952	·34	10624	·43	9562	·53
16	18128	·18	15536	·24	13584	·32	12080	·40	10880	·5
17	20500	·17	17500	·23	15353	·3	13647	·38	12282	·47
18	22932	·16	19656	·21	17208	·28	15700	·36	13752	·44

Note.—This Table shows the greatest weight that ever ought to be laid *upon a beam for* permanent load, and if there be any liability to jerks, &c., *mple allowance* must be made; also the weight of the beam itself mus *uded.*

To find the weight of a cast-iron beam of given nensions.

Rule.—Multiply the sectional area in inches by e length in feet, and by 3·2, the product equal the ight in lbs.

Ex. Required the weight of a uniform rectangular am of cast iron, 16 feet in length, 11 inches in eadth, and 1½ inch in thickness.

11 × 1·5 × 16 × 3·2 = 844·8 lbs.

sistance of bodies to Flexure by vertical Pressure.

When a piece of timber is employed as a column or pport, its tendency to yielding by compression is ferent according to the proportion between its length d area of its cross section; and supposing the form it of a cylinder whose length is less than seven or ht times its diameter, it is impossible to bend it by y force applied longitudinally, as it will be destroyed splitting before that bending can take place; but en the length exceeds this, the column will bend der a certain load, and be ultimately destroyed by imilar kind of action to that which has place in e transverse strain.

Columns of cast iron and of other bodies are also nilarly circumstanced, this law having been fully veloped by the experiments of Mr. Hodgkinson columns of different diameters, and of different gths.

When the length of a cast-iron column with flat ds equals about thirty times its diameter, fracture ll be produced wholly by bending of the material; when of less length, fracture takes place partly by ushing and partly by bending: but, when the column is enlarged in the middle of its length from one d *a half to* twice its diameter at the ends, by being cast hollow, the strength is greater by $\frac{1}{7}$th than in a solid column containing the same quantity of material.

To determine the dimensions of a support or column to bear without sensible curvature a given pressure in the direction of its axis.

Rule.—Multiply the pressure to be supported in ℔s. by the square of the column's length in feet, and divide the product by twenty times the tabular value of E; and the quotient will be equal to the breadth multiplied by the cube of the least thickness, both being expressed in inches.

Note 1.—When the pillar or support is a square, its side will be the fourth root of the quotient.

2. If the pillar or column be a cylindar, multiply the tabular value of E by 12, and the fourth root of the quotient equal the diameter.

Ex. 1. What should be the least dimensions of an oak support, to bear a weight of 2240 ℔s. without sensible flexure, its breadth being 3 inches, and its length 5 feet?

Tabular value of $E=105$,

$$\text{and } \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8{\cdot}888} = 2{\cdot}05 \text{ inches.}$$

Ex. 2. Required the side of a square piece of Riga fir, 9 feet in length, to bear a permanent weight of 6000 ℔s.

Tabular value of $E=96$,

$$\text{and } \frac{6000 \times 9^2}{20 \times 96} = \sqrt[4]{253} = 4 \text{ inches nearly.}$$

pressure with safety.

Diam. in inches.	Length or height in feet.										
	4	6	8	10	12	14	16	18	20	22	24
	Weight or load in cwts.										
2	72	60	49	40	32	26	22	18	15	13	11
2½	119	105	91	77	65	55	47	40	34	29	25
3	178	163	145	128	111	97	84	73	64	56	49
3½	247	232	214	191	172	156	135	119	106	94	83
4	326	310	288	266	242	220	198	178	160	144	130
4½	418	400	379	354	327	301	275	251	229	208	189
5	522	501	479	452	427	394	365	337	310	285	262
6	607	592	573	550	525	497	469	440	413	386	360
7	1032	1013	989	959	924	887	848	808	765	725	686
8	1333	1315	1289	1259	1224	1185	1142	1097	1052	1005	959
9	1716	1697	1672	1640	1603	1561	1515	1467	1416	1364	1311
10	2119	2100	2077	2045	2007	1964	1916	1865	1811	1755	1697
11	2570	2550	2520	2490	2450	2410	2358	2305	2248	2189	2127
12	3050	3040	3020	2970	2930	2900	2830	2780	2730	2670	2600

Practical Utility of the preceding Table.

. Wanting to support the front of a building with iron columns 18 ft. in length, 8 inches in diameter, the metal 1 inch in thickness; what weight may

I confidently expect each column capable of supporting without tendency to deflection?

Opposite 8 inches diameter and under 18 feet=1097
Also opposite 6 in. diameter and under 18 feet= 440
= 657 cwts.

Note.—The strength of cast iron as a column being 1·0000
" steel " = 2·518
" wrought iron " = 1·745
" oak (Dantzic) " = ·1088
" red deal " = ·0785

Elasticity of torsion, or resistance of bodies to twisting.

The angle of flexure by torsion is as the length and extensibility of the body directly, and inversely as the diameter; hence, the length of a bar or shaft being given, the power, and the leverage the power acts with, being known, and also the number of degrees of torsion that will not affect the action of the machine, to determine the diameter in cast iron with a given angle of flexure.

Rule.—Multiply the power in ℔s. by the length of the shaft in feet, and by the leverage in feet; divide the product by fifty-five times the number of degrees in the angle of torsion: and the fourth root of the quotient equal the shaft's diameter in inches.

Ex. Required the diameters for a series of shafts 35 feet in length, and to transmit a power equal to 1245 ℔s., acting at the circumference of a wheel $2\frac{1}{2}$ feet radius, so that the twist of the shafts on the application of the power may not exceed one degree.

$$\frac{1245 \times 35 \times 2{\cdot}5}{55 \times 1} = \sqrt[4]{1981} = 6{\cdot}67 \text{ inches in diameter.}$$

Relative strength of metals to resist torsion.

Cast iron	=1	Swedish bar iron...	=1·05
Copper	= ·48	English do. ...	=1·12
Yellow brass......	= ·511	Sheer steel	=1·96
Gun metal.........	= ·55	Cast do.	=2·1

SMELTING.*

GOLD AND SILVER ORES, &C.

the assay by fusion the object is to produce a
l in its pure form, directly from the ore, and in
e instances to produce all the metal of a certain
which the ore may contain, with a view of
paring the result of the assay with the smelting
ess on the large scale. To succeed we must
idise the ore, and produce at the same time so
h heat as to melt the metal; in addition, the
ign matter in the ore must be converted into a
le scoria, which generally floats as a light glass
he top. Different ores require different modes
peration to produce the metal. Often a variety
he same ore must be subjected to different pro-
es. For the latter reason we convert most ores,
h are to be examined, into oxides by roasting.
n a specimen is to be assayed we ought to know,
ast approximately, its composition, in order to
ify the manipulation accordingly. In most in-
ces we recognise the quality by the appearance
e ore; in others, we apply the blow-pipe as an
ductory examination. We shall, in order to
itate the operation, describe the most prominent
ks of the ores which may come under examina-

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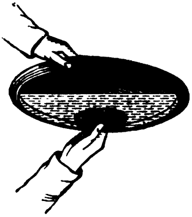
* Overman's 'Treatise on Metallurgy,' 8vo.

tion, and the class to which they belong. If an assay is ineffectual at first, it is repeated with proper modifications until a satisfactory result is obtained. There is not much difficulty in this, as it chiefly requires the production of a suitable slag.

Gold.—An assay of gold ore is not difficult. If we expect gold in a specimen, we pulverise it finely; then pass it through a fine sieve, and wash the powder in an iron pan, or a blackened pan of any kind of material. The annexed figure represents the manner in which the operation is performed. A pan is held in one hand firmly, and some water poured upon the ore; the other hand is now used for shaking the pan in a gentle but rapid manner. The powdered ore being thus gathered to one side, the heavy grains of gold descend through the sand to the bottom of the pan, and settle in the corner. After shaking the pan a few minutes, it is to be moved so as to produce a gentle current in casting off the water. This will carry with it some of the sand, and diminish the quantity in the pan. In repeating this process with fresh water, another portion of sand is removed from the sample; and if the shaking and removal of sand is continued, the latter may be washed off entirely, or nearly so. The principle involved is, that the debris of rock is lighter than the gold; the latter will therefore sink to the bottom, and the former pass off, by moving the water gently on the surface of the pulverized ore, which is always retained in the same place, in a corner of the pan. When the sand is thus nearly washed away, a little water is retained



in the pan, moved around by inclining the pan, so that the water flows always into its corner or lowest part. This gentle current will move the debris of rock to another part of the pan, and expose the metal to view. When this operation is performed on crushed rock, or on alluvial soil, it is in all cases necessary to pulverize the mineral, that no particle of metal may escape detection. In this manner we cannot make a quantitative assay; for, with the greatest attention, we lose half of the metal. Gold is very fine when its ore has been crushed, and it is carried away by the water in washing off the rocky matter. In most cases we detect the gold in its metallic state. When an ore is thus treated, and we do not find it in the residue—which may happen in silver ores, in the tellurets, and sulphurets, and arseniurets—we crush the ore, as before, mix it with the fluxes, and smelt it.

Gold ores are not often so rich in metal that a small quantity smelted would furnish a safe estimate of the average contents of a mine. It is therefore necessary to assay at least 500 or 1000 grains at once, and repeat this operation on various parts of the vein. If the ore is a ferruginous slate, or quartz, it is intimately mixed with half its weight of pure litharge, half its weight of borax-glass, and one part of carbonate of potash: these ingredients must be well dried, and the whole then finely pulverized. This mixture receives an addition of sufficient carbon to precipitate a certain quantity of lead in the metallic state; and as one part of charcoal produces 30 parts of metal, we add accordingly. From 1000 grains of ore, 100 grains of lead may be produced, which will contain all the gold present; and in order to obtain these, we add 4 grains of fine charcoal and mix it intimately with the ore and flux. Here is more carbon than is required, but we must consider that a little carbon is always lost in the operation. This mixture is put into a Hessian crucible, which should not be more than half filled; for the mass, when heated, will boil and overflow the brim of the pot. Instead of carbon, black flux might be used; but as we do not know the amount of carbon in that flux exactly, we are exposed, in using it, to the producing of too much or too little lead. Over the test in the crucible a little common salt, a stratum of about a quarter or half of an inch thick, is laid, which will prevent the evaporation of carbon, and accelerate the solution of metallic substances in the ore. The use of a graphite, or black-lead crucible, is inadmissible in this case; for its carbon would precipitate more lead than is needed, and cause it to be impure. The crucible and contents are now placed in the furnace, covered by a slab to prevent the falling in of coal, and surrounded with coal so as to cover the crucible; fire is then applied at the top by adding hot charcoal. The fire thus kindled will heat the crucible from the top downwards, which protects the pot and prevents its fracture. In half an hour the fire should be drawn to the grate-bars, and fresh coal added, sufficient for at least three-quarters of an hour; the furnace is then covered, the grate cleaned, and a vigorous heat applied. In half an hour the furnace-cover is partly removed, the cover of the crucible lifted, and the contents examined. If the mass is fluid but still boiling, that is, throwing up gas-bubbles, the pot is covered again; and when there is a deficiency of coal to last the heat out, a fresh supply is added to complete the assay. When *coke* or anthracite is used, we need not add fresh

uel to a once charged furnace; the use of charcoal,
owever, makes this invariably necessary. As the
ddition of fresh fuel delays the operation, and is in
ome cases injurious to the assay, we see the import-
nce of using hard coal, either coke or anthracite, in
rucible smeltings. A strong heat, and one of short
uration, is all-important in this assay; for lead is
olatile, and the flux will at last eat through the
rucible.

After the lapse of about ten minutes, the contents
f the crucible are again examined; and if the mass
s now found to be perfectly fluid and quiet on its
urface, the covers of the furnace and pot are re-
oved, the fuel rammed down by means of an iron
od, and the crucible withdrawn from the fire and set
a dry or warm place on the brick floor. The cru-
ible may be withdrawn by a pair of blacksmith's
ongs, the fire-lips of which are nearly as long as the
hanks, thus causing very little pressure upon the
ides of the pot. Basket tongs may also be used,
imilar to those of the brass-founders; but they are
enerally too heavy and clumsy for assaying opera-
ions. On putting the crucible down on the floor,
ome few gentle taps are given to it, to gather in the
ottom those globules of metal which are suspended
the slag. When the crucible is perfectly cool, it
s broken over a basin with water, that its contents
ay be examined when wet. In the bottom of the
ot, a button of lead is found; and on breaking the
coria, we may examine it for grains of metal. If no
etal is visible with the aid of a lens, all the parts of
e pot and the slags are thrown away; if metal is
isible, the pot and slag is to be pulverized, and
ashed, so as to recover it. This operation is per-
rmed in a wash-pan, like that with the crude ore

above described. All the metal must be freed from adhering slags by means of the hammer and water; it is then weighed and a cupel selected of equal weight, or heavier, for refining it.

Use of Salt.—In this assay we recommend the use of salt in the form above mentioned, and not mixed with the ore and other fluxes. Salt is not a good flux, because it does not aid in the solution of silex directly; it merely dissolves the metallic oxides and prepares them to combine with silex. Most of the metals combined with chlorine are very volatile, and in assays, other than those of the precious metals, salt is inadmissible. Saltpetre is preferable to salt; but as the oxygen of the saltpetre is soon absorbed by the carbon present in the mixture, no lead will be precipitated; or else all the saltpetre will be converted into alkaline flux, which is not a proper flux for gold or silver ores; it causes the lead to be so impure as to cupel with difficulty. Some common salt, or fluor-spar, is requisite to free the lead from iron, copper, and such metals, which delay and often spoil the cupelling of it. In these assays it must be the aim of the assayer to obtain pure lead in the first smelting; if it is not obtained, it must be remelted with a little saltpetre, or a mixture of saltpetre and common salt.

Sulphurets and Tellurets.—When gold ores are not perfectly oxidized, which frequently happens,—when pyrites are present, or the gold is combined with tellurium or galena,—the operation is somewhat difficult if we expect a correct quantitative assay. In this case, as well as in the foregoing, we may assay by means of litharge, using four or five parts to one part of ore, or, in fact, any quantity more or *less than* that specified, and precipitate as much lead as we want by means of a specified quantity of coal or black flux. Such an assay is never correct; the slag is decidedly alkaline, and it retains a portion of the precious metal which may amount to 10, or 20, or even a greater per-centage of that contained in the specimen. In all cases when precious metals are to be assayed, and the object is to obtain the whole amount, the slag which is formed ought to be of an acid nature; if not acid, it should be, at least, a neutral salt. Gold is soluble in an alkaline slag, particularly in an alkaline sulphuret; and it cannot be expected to follow the metallic lead when so dissolved, or suspended in the slag. The means commonly employed for the purpose have proved insufficient, and the author has been induced to perform a series of experiments which resulted in a more perfect mode of assay, and in a smelting operation, the benefits of which he has secured to himself by a patent right. This operation is as follows. When the ore contains sufficient galena, no lead is added; but when it does not contain lead in some form or other, some finely-powdered litharge is added to the pulverized ore, and the whole intimately mixed. From ten to fifteen per cent. of oxide of lead is in all cases sufficient to procure all the gold. The pounded ore and litharge is mixed with about one half of its weight of common salt; the whole mass is moistened with water so as to dissolve the salt, and then exposed to evaporation under constant stirring. When dry, the contents are gently heated in an iron pot with a concave bottom, and as soon as any signs of melting are perceptible, the mass is diligently stirred by a bent iron rod. It soon becomes semifluid, and the heat should be modified so as not to make the slag perfectly fluid and evaporate the chlorine, for the latter must be retained. When the slag has been well stirred for a short time, a few small pieces of burning charcoal are added, and stirred with the cinder. The charcoal reduces the oxide of lead, and the heat must be so regulated that no lead can sink to the bottom of the pot, but is suspended in the semi-fluid slag. By constant stirring, the particles of metallic lead absorb the particles of gold which may be suspended or dissolved in the semi-fluid sulphuret, and an alloy is obtained, disseminated in small globules through the mass. About half an hour is sufficient time to finish this smelting operation; the iron pot is removed from the fire, and the mass quickly thrown into cold water. Then the slag dissolves, the salt is extracted, and there remains in the vessel, a black, fine powder, which feels like plumbago; it consists of the sulphurets of various metals, and metallic lead in small grains and spangles. The sulphurets are extremely fine, and are held in suspension in the strong brine. Fresh water should be added at discretion, the sulphurets gently washed away, and the remaining lead gathered for cupellation.

By this mode of assaying, all the gold is easily obtained, but it requires a low heat and diligent work to make the operation successful. If sufficient iron pyrites is present, the addition of a little lead serves to secure the precious metal; if there is only a little iron in the ore, a small quantity of oxide of iron should be added to decompose the sulphurets. A gentle heat, the presence of salt, and the stirring, cause the evaporation of some sulphur, also arsenic and tellurium, and the sulphurets are thus deprived of the power to dissolve gold. The gold is now *suspended* in the pasty mass, and obtained by combining it with metallic lead. If the combination is produced when the mass is in a state of rest, many particles of gold may be lost, because they are fine, and washed away with the water and the fine sulphurets; diligence is therefore necessary to make the operation succeed well. The presence of any alkali will injure this operation, and if some of the lead remains in the form of a sulphuret in the slags, the assay is doubtful. There is no danger of reducing the ores of iron, copper, or other metals by carbon; gold, silver, the platinum metals, and lead, are the only ones which can be obtained. The addition of an excess of carbon under the influence of a limited heat has therefore no other effect than to increase the mass and the labour in washing. The lead obtained in this operation may be re-melted in a crucible along with a little saltpetre, to form it into a button and to free it from impurities.

In ancient times, assayers melted pyrites in potash and soda, and dissolved the slag in warm water, supposing that all the gold was contained in the alkaline sulphuretted solution. But this was a mistake: gold is soluble only in alkalies which contain a large quantity of sulphur. Sulphur must, therefore, either be added to such an assay, or the gold will adhere to the metallic sulphurets and be precipitated with them. It is very doubtful if with the addition of sulphur the whole amount of gold is obtained in the solution, because it is not very soluble in that menstruum. Other metallurgists recommend to melt the pyrites with saltpetre and litharge, then to evaporate all the sulphur and produce metallic lead. This is a safe way of assaying, but as saltpetre is easily decomposed and forms an alkaline slag, it requires either a very large quantity of the flux, or the assay is incorrect. It needs at least an amount of saltpetre equal to that of the ore when clean, and if the slag is not very liquid, a part of the gold will remain in it. The method of roasting or oxidising the pyrites, and removing the oxide by washing, is so imperfect that it deserves no further notice.

If gold is contained in metals, such as refuse iron, tin, zinc, brass, or copper, under the form of works of art, it is scraped off with a scraper or file. This labour may be accelerated by oxidising the metals at a low heat. The gold thus obtained, as well as jewellers' sweepings, are either melted with saltpetre, or with saltpetre and lead; in the latter case, some lead is obtained which contains all the gold, and may be cupelled in the usual manner. In this case tin or zinc is frequently present in the refuse, and as the oxides of these metals do not melt in saltpetre, it is advisable to add some common salt to the assay, to remove them from the lead, for these render the operation of cupelling slow and tedious; and if zinc or antimony is present, some of the gold is carried off by the evaporation of these metals. If sufficient saltpetre is used, and a little common salt, there will not be any other metals than lead and gold or silver in the button. It has been proposed to free gold from other metals by means of sulphuret of antimony; but this operation, which is generally practised by jewellers for refining their gold, is not applicable to an assay, because it is never correct. It has been also proposed to oxidise artificially all the metals which may be combined with gold, by using black manganese or oxide of iron. This method is not sufficiently correct to deserve any notice; for in all instances the oxides which are formed contain gold in small particles which never can be recovered.

The true principle of an assay for gold, in all cases, is to form a very fusible slag, which absorbs all the metals; and as the gold will adhere readily to melted lead, it should be brought in contact with that metal in a state of fusion, and all the particles will be obtained. Common salt, or borax, remarkably promotes the solubility of metallic oxides, and in fact dissolves them very readily. In all cases, therefore, where we have to deal with metals or metallic oxides, either one or the other should be present; but, as borax causes other metals than lead to be formed, and salt produces only the precious metals and a limited quantity of lead, the presence of the latter is, in all cases, preferable to borax, when the precious metals are the object of the assay. There is no substance which dissolves metals more readily and converts them into oxides, than chlorine, and when this is present in a sufficient quantity, the precious metals are not excepted; but when metallic lead is once produced in a crucible, it is only necessary to bring the dissolved gold in contact with the lead, and it is absorbed by it.

Metals and Gold.—When other metals are alloyed with gold, we separate the first either by cupellation, or if the kind and quantity is not suitable, we convert the first into oxide, and divide the latter. The alloy of lead and gold is the most suitable for cupellation, and it is in all cases advisable to remove all other metals and convert the alloys into this combination. As gold is very volatile, these conversions must be performed by as low a degree of heat as possible. The cupellation of lead and gold is perfectly safe and easy: this is not the case with other metals and gold. Copper and gold combine very readily, and in fact mcre so than lead and gold, but this alloy cannot be cupelled: it is therefore melted with lead, and the latter causes the oxide of copper to be absorbed by the cupel. The operation is uncertain, for the oxide of copper will absorb gold and carry it off. Such an assay is never correct, the refined gold containing copper, and the oxide of copper, gold. The same is the case with all other metals, and it is an object of peculiar importance not to cupel a test wherein other metals or substances than lead are contained. Other alloys than those of lead should be dissolved in muriatic acid, and precipitated by carbonate of soda, and the precipitate smelted like a mineral. In smelting, an excess of litharge is used; the quantity of lead is determined by the carbon which is added. An alloy of copper and gold requires a large quantity of lead for cupellation. We may assume that 100 parts of lead to one of copper is not too much, considering their relation, and the uncertainty of success in such an assay. It is easily understood that the solution of the alloy, and its precipitation with an alkali, is the only safe way of proceeding. As an alloy of gold always contains some silver, and as gold is not soluble in muriatic acid, the remaining parts which do not dissolve in the acid must be smelted with the precipitate. There would be no necessity of precipitating the solution, and merely smelting the residue would answer the purpose, but for the circumstance that chloride of silver is soluble to a certain extent in other or soluble chlorides: and as in most cases the amount of foreign metals is small, this method does not increase the labours of the assayer.

If the quantity of a metal in a test specimen is large, it is advisable to make a sulphuret of the *alloy*. This is accomplished in melting the specimen, by adding gradually sulphuret of iron, coarsely pounded. The native pyrites contain sufficient to produce this effect on a large quantity of other metals. Galena may be used also, but it is not so effectual as iron pyrites. If neither iron nor lead pyrites can be obtained, pure sulphur is used, which is added to the melted or heated metal in small quantities and in the form of a coarse powder. The resulting sulphuret is then treated as native sulphurets, as has been stated in former pages.

Platinum, Silver, and Gold.—The presence of the first of these metals causes the cupellation to work slowly, and in some cases, particularly when copper is present, the gold does not form a globule at all, but is carried with the oxide of copper and the platinum metal over the cupel. In such cases we melt the test with some silver, of which at least twice the amount of the gold alloy must be added, and also some lead to make the mass fusible ; it is then cupelled in a strong heat, to obtain the metal in a perfect globule. The quantity of lead is variable ; if the heat in the cupel is strong, which is the most advantageous, the quantity of lead may be 12 or 14 times that of the alloy. If the heat is low, but sufficient to melt the alloy, the quantity of lead must be at least 20 times that of the alloy. In all cases the resulting refined metal is adulterated by copper, if that metal is present, which is more likely to be the case if the heat has been low in the cupellation. If no copper is present, less lead may be used in refining the metal. The presence of platinum in a test is recognised by the globule, which assumes a flattened instead of a round form,—this is pre-eminently marked in pure gold ; silver, or an alloy with much silver, is also liable to form a flat globule in the shape *of a hemisphere,* while that of platinum is distinctly flattened. One per cent. of platinum will cause the globule to be rough and rugged on the surface, while pure gold and silver is perfectly smooth and shows a mirror-like lustre. In all cases the presence of platinum causes the globule to be dull and lustreless, often showing crystals on the surface. When the alloy contains more than ten per cent. of platinum, the cupel is covered with a silver coating, under the influence of a strong heat, which is often yellowish or grayish, and consists of platinum metal.

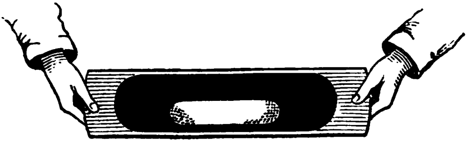
Moist analysis.—When a globule of gold is obtained in the process of cupellation, it is never pure, particularly when derived from a mineral. The globule, for the purpose of testing it, is flattened on a steel anvil with a hammer; at first it is placed directly on the naked steel, and afterwards between strong and thin paper. It is next exposed to the influence of pure nitric acid, which must be free from muriatic acid, which will not cause a precipitate with nitrate of silver. If the gold is nearly pure it is not attacked by the acid; we melt it then with some pure lead, about equal to twice its weight, and dissolve this alloy. The nitric acid, gently heated, will now hold in solution the lead and silver, and leave gold, platinum, and the platinum metals at the bottom of the vessel. If pure silver is at hand it may be melted with the globule, of which an equal weight is sufficient. The result is more certain than by alloying it with lead. The residue of the solution is treated with aqua regia, which dissolves the metal. The solution thus obtained is evaporated in a flat porcelain dish, over a basin of boiling water, which causes the evaporation of all the acid. The dried chloride of gold is now dissolved in water, and to this is added a fresh solution of proto-sulphate of iron, which in a short time precipitates the gold in the form of a yellowish brown powder. This is dull and lustreless, but assumes brightness when filtrated, dried, and burnished by a hard and polished substance. The proto-sulphate of iron is prepared by dissolving copperas, and adding to the solution pure metallic iron. This solution must be prepared some days previous to its use, for the iron does not dissolve very readily in the copperas. A surplus of metallic iron should always be in the solution. It is advisable to use both gold and iron solutions in a somewhat diluted state; it does not then form a precipitate at once, but requires some time. The mixed solution appears at first to be light blue, and in reflected light reddish yellow; the gold gradually subsides in the form of a yellow powder. This powder is pure gold; it is filtrated on clean paper, and may be weighed in this state, or it may be gathered into a globule with some borax and saltpetre in a crucible.

Remarks.—In all the assays of gold, we must be extremely cautious to avoid the presence of an alkaline slag; for in most cases some oxide or sulphuret of gold is always present in a mineral which contains gold. Both are soluble in alkalies, and if the slag we melt with is alkaline, we are uncertain of the results of the assay. Borax, potash, and soda are to be avoided, if possible; and the use of salt requires caution, for all these fluxes dissolve gold. Saltpetre is the most suitable flux, but in the presence of sulphur, carbon, and some of the metals, it is decomposed, and ceases to be good. Chlorides are the most practicable fluxes; but as these cannot bear a high heat, nor one of long duration, the operation must be so arranged as to perform the assay in the shortest time which is possible. For these reasons the fluxes and mineral are mixed in a wet condition, to bring the particles in close contact before heat is applied—this facilitates the smelting considerably. The moistened mass must be dried before it is packed into an earthen crucible, because it will break the crucible when it is deposited in a moist state. Gold is not often found in large quantities in minerals; and as a minute quantity is sufficient to pay for its extraction, the assay of gold ore claims an attention which is not required in assaying the ores of other metals. Chlorides dissolve the oxide of gold, but not metallic gold; and when fluid lead is brought in contact with the dissolved oxide or sulphuret, it will absorb them; but as lead is heavy, it is inclined to subside, and thus deprives the particles of gold, which still may be present in the slag, of an opportunity to combine with it: for these reasons we prefer the assay in an iron pot, with a constant stirring of the mass. The melted lead performs here the office of mercury in an amalgamation.

Platinum and Platinum Metals; Palladium, Rhodium, Iridium, Osmium. The latter metals are generally alloyed with platinum. Platinum is exceedingly refractory; it can be melted only when alloyed with another metal. When a grain of metal of a leaden appearance resists all degrees of heat, and neither melts nor oxidises, we may conclude that it is platinum. If the grains of the metal are fine, and imbedded in rocky matter, it is treated as gold ore, melted with suitable fluxes, and cupelled. In this case silver must be present to cause the platinum to be fusible in the cupel. If no silver is in the ore, an addition of pure metal must be made to the assay. In a strong heat, platinum combined with two parts *of silver may* be cupelled. But as a strong heat is not generally at the command of the assayer, it is advisable to make use of more than two parts of silver to one of platinum. In most cases it is the best plan to arrange the assay so that one part of platinum in the ore is melted with 6 parts of silver and 50 parts of lead. If less lead and silver is in the alloy, the metals palladium and rhodium do not remain in the globule, but are spread over the cupel. If the amount of platinum in the test is not more than five per cent., or $\frac{1}{20}$ of the silver, the appearance of the globule in the heat of the cupel is similar to that of pure silver. If $\frac{1}{10}$ of platinum is in the silver, the globule does not show the bright glistening surface of silver or gold, but is dull and gray. With $\frac{1}{4}$ of platinum it requires a strong heat, and the cupelling is extremely slow; the grain is flattened, dull, and obstinately retains the last portions of lead. The globule thus obtained in cupelling contains silver and platinum, and it may also contain gold and other metals; if thrown into concentrated boiling sulphuric acid, all the silver is dissolved, but not the platinum. The residue is platinum, and if gold has been in the alloy, it contains gold. It is then dissolved in aqua regia, some ammonia is added, and the solution evaporated over boiling water. The dry residue is triturated with alcohol of ·84 specific gravity, and dissolved in water after the alcohol has extracted the yellow liquid. The gold only is dissolved; the platinum remains as a platinum chloride combined with chloride of ammonia. This is calcined in a red heat over the spirit-lamp, and the remaining powder, which is platinum, weighed. The gold may be obtained by means of proto-sulphate of iron. Too much silver in the alloy is not good for solution, because some little platinum appears to be soluble in sulphuric acid when the amount of silver is more than 2 to 1 of platinum; but as this loss is very small, the assay indicates too little metal. When iridium is present, the precipitate of platinum-ammonium chloride is reddish or brick-red, instead of yellow. The precipitate is then calcined in a porcelain crucible and dissolved in aquafortis, which alone dissolves platinum; this, when precipitated by ammonia, forms a yellow precipitate. The separation of the other platinum metals from the solution, is, if not difficult, at least of such a nature as to belong more to chemistry than to metallurgy.

Silver.—The assay of silver ore is, in itself, extremely simple. Most of the silver ores contain lead, others copper, which metals in many instances so far predominate as to make their extraction profitable. We make the assay in this case with a view to procure the accompanying metal. In all cases it is necessary to combine the silver with some lead in smelting, and separate the silver by cupellation. If there is not sufficient lead in the ore, litharge must be added to increase it. The test can be melted with metallic lead, also, in case litharge cannot be obtained sufficiently pure. Metallic lead should be pure. It may be tried by cupelling a part of that which is designed to form the matrix for the silver. If it proves to be pure in the cupel—that is, shows no other colours, but converts that of the cupel into a uniform whitish-yellow, and no metallic globule remains—we may conclude the metal to be sufficiently pure for the purpose. The assays with metallic lead, and those with the oxide of lead, have their peculiar advantages: the first is for quantitative assays in the smelt-works; the second is the most convenient for qualitative assays.

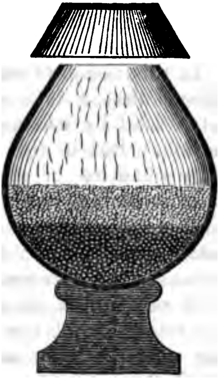
lssay by Metallic Lead.—We thus assay all the
; in which we expect to find silver or other pre-
ls metals. The lead used in this assay, the
ity of which has been tested, is granulated in the
owing manner. The metal is melted in a clean
l ladle, the dross or sullage on its surface is re-
ved, and the liquid poured into a wooden trough,
ch is previously rubbed over with reddle, in order
prevent the burning of the wood. The trough is



resented in the annexed figure. It is taken up
h both hands, and the lead kept constantly in
tion until it is near congelation; at this point the
l is thrown up, and in falling back into the
ugh again it is broken into small fragments, which
often very minute, and the mass appears in the
m of fine sand if the operation has been well per-
med. When all the lead is thus divided, and
d, it is thrown on a sieve, of about twenty meshes
the inch; the fine part is removed for use, and
: coarse grains which remain are reserved for re-
lting. This lead, in quantities of two ounces for
e test, is placed upon a flat dish, and mixed with
: ore for smelting. The dishes used for this pur-
se are manufactured of good fire-clay, similar to
it of which crucibles or fire-bricks are made; a
xture of three parts of pure clay and four parts of
ractory sand is considered a good composition.

Dishes of three inches diameter are made by hand of this siliceous clay, but where many are required, it is necessary to manufacture them by such a machine as is used for making cupels. The capacity of the dish must be abundantly sufficient to melt four ounces of lead and half an ounce of ore. These dishes, when first made, are too soft and porous for use: they are dried in the air and then baked in a furnace. Any potter can manufacture and bake them with his ordinary ware. With a cupel furnace, having a large muffle, a number of tests may be assayed at once; and in all cases, two tests should be assayed from every species of ore. Whenever meltings, smelting, and cupelling, are done at the same time, the dishes, pots, or cupels, are marked with reddle, and numbered in such a manner that each test may be recognised: this reddle mark is not obliterated by fire. Two ounces of granulated lead are laid around the edge of the dish, so that the concavity in the centre is free. In the middle, $\frac{1}{8}$ of an ounce, or 60 grains, of ore finely pulverized, is placed, and some of the granulated lead mixed with it, in such a manner that the ore does not reach to the edge of the dish. The dishes thus prepared with ore and lead are pushed slowly into the heated muffle of the furnace; the most refractory specimens foremost, and those afterwards which melt easily. The ores which contain much siliceous matter or iron are refractory: those which contain pyrites chiefly, are very fusible. In a short time, say five or eight minutes after exposure to the heat of the muffle, the ore begins to roast, that is, exhale sulphur, arsenic, and other volatile substances, and the lead begins to melt. When ore *and metal* are thus heating, the mouth of the muffle *is shut by* a piece of hard charcoal, and the dishes, gradually exposed to a stronger heat by stirring the fire: this must not be done too fast, because some ores foam in melting and flow over the lead, thus spoiling the assay. The principal object of this operation is to form a slag of the ore, and bring at the same time melted lead in contact with it in its molten state, which may absorb the precious metal. In case the ore does not contain sufficient flux for melting, some of the lead is oxidized by the heat, and forms a flux for it. It is therefore evident that too much heat is disadvantageous to the ore, because some of it may boil over the edge of the vessel and is lost. The heat must not be too slow to act, because in that case, the oxide of lead, which is generated abundantly, will eat through the dish. The heat in the muffle is easily regulated by putting more or less coal at the mouth. It is therefore advisable to have the fire rather too strong than too weak. After the lapse of fifteen or twenty minutes we observe a bright metallic spot in the middle of the dish. It is the melted lead surrounded by the fluid ore, which is now in the form of a slag. The lead is all the time burning and evaporating; and if these vapours of it draw over the dishes, it is an indication that the heat is too low; on the other hand, if these vapours rise high on the roof of the muffle, the fire is too hot. The vapours of lead ought to form a cloud, which is suspended half-way between the roof and the bottom of the muffle. The withdrawal of coal at the mouth of the muffle will cool it, and the addition of coal heat it. When the bright spot in the middle of the dish disappears, the mouth of the muffle should be entirely shut, and a strong heat applied about ten minutes longer. This is the finishing heat; the ore becomes now perfectly fluid, and separates entirely from the button of lead below it. This heat is sufficient to finish the operation. The time consumed in the assay is between one hour and one and a quarter. The dish is now withdrawn from the hot muffle, and its contents cast into a previously heated iron mould which has been rubbed over with some fat or tallow. After the contents of the mould are cooled sufficiently to adhere together, they are put into cold water, and the slag carefully separated from the lead by striking it with a hammer. This lead is ready for refining, and may be placed in the cupel. In case the ores contain very refractory matter, such as particles of clay, slate, heavy spar, and quartz, about ten grains of borax-glass may be mixed with the ore; but if the test will work without, it is better. If a series of tests are to be assayed, it is the best plan to melt the whole of them before refining the lead.

Smelting with Oxide of Lead.—All ores may be smelted with the oxide of lead instead of metallic lead, which is preferable when much lead is in the ore. Some ores must be roasted before melting; these do not often present themselves, and generally we may smelt without previous roasting. The ore under examination is finely pounded, and mixed with double its weight of a mixture consisting of one part of saltpetre and two parts of crude cream of tartar. This is the composition of black flux, which may be used here to advantage in its crude form, particularly when sulphur is in the ore. The use of this mixture presupposes the presence of lead in the ore, and one ounce is smelted at a time; this brings the quantity of ore assayed to near five hundred grains. If no lead is in the ore, or very little, an equal weight *of pure lith*arge is mixed with it, and the other proportions are the same as mentioned before. In most cases it is the best plan to take 100 grains of this kind of ore, and mix with the required flux for smelting. If we want a correct assay of lead, the test is not smelted in an earthen or clay crucible, but in a copper pot, so that all siliceous matter is excluded. In the figure annexed, a pot of this kind is represented. It is about ¼ of an inch thick in metal, and as the flux is exceedingly alkaline, very little lead can remain in an oxidized state in the slag. Over the mixture of ore and flux a stratum of salt is laid. This is necessary to prevent the flying of the ore. The crude flux, in detonating with the saltpetre, would throw out the ore unless it was covered with salt, especially if the narrow mouth of the copper pot was open. A short time, 35 or 40 minutes, is sufficient to smelt the test, for which of course the heat must not be made so high as to melt the copper. This test may be smelted in an iron pot if the ore contains no sulphur. When the smelting is finished, the contents are poured into the iron mould, and the quantity of lead which is obtained shows the exact quantity of that metal in the ore.



When oxide of lead is added to the assay, no test can be made for determining the quantity of lead. The operation is essentially the same as that above mentioned, and may be performed in a clay or Hessian crucible, in a black lead pot, or an iron pot. The lead thus obtained is cupelled. In all cases where crude tartar is used as a flux, the fire must be kindled above the pots, for if it comes from below, the detonating saltpetre is apt to throw most of the ore out, in spite of all precautions. The fire must be low so long as a noise is perceived in the pot; when that ceases, the draught-holes may be opened and more fire applied.

In this assay we may use litharge, as in the gold assay; that is, take an excess of litharge and precipitate lead by mixing with it a definite quantity of carbon. But in this case, as in the previous one, a large quantity of silver may remain in the slags. This is of less importance than in the case of the gold assay; still it is sufficient to cause an assay made in a clay crucible to be incorrect. In all these instances we recommend smelting in an iron pot, with salt and a constant stirring of the mass, and the extraction of the granules of lead by dissolving the cinder. This assay furnishes a more correct result than any other.

When sulphurets are extensively present in an ore, the operation is in all cases performed with greater facility if the test is smelted with saltpetre only, or a mixture of saltpetre and litharge, to which carbonate of soda is added. Galena may thus be conveniently assayed for silver, if we pound it with three or four times its weight of saltpetre, and dry carbonate of soda of a weight equal to its own, or the same quantity of oxide of lead. Thus a small quantity of lead is produced which contains all the silver, but not all the gold if any is present. The sulphurets may be also smelted in a clay pot, with just *sufficient* saltpetre to oxidize all the sulphur and produce no metallic lead. The slag thus formed is covered by a sheet of metallic lead, which in melting down carries all the silver with it. This operation may be correct when executed properly, but it is one of those difficult assays in which the result depends on the skill of the operator. When an assay is performed in an iron pot, under constant stirring, all the sulphurets of an ore may be decomposed by litharge; when to this, metallic lead is added and the assay in its fluid state is poured into a hot clay crucible and rapidly melted, so as to accumulate all the metal at the bottom, we may obtain all the silver in the ore, but not all the gold. If a mixture of ore and flux of litharge is so regulated as to form an oxide, the ore never boils on melting; we may therefore in such a case fill the crucible, and cover the top of the ore with pure litharge. As much metallic lead will be produced as is indicated by the amount of sulphur in the ore, which in iron and copper pyrites is considerable. An assay of this kind must be made in the shortest possible time, for the litharge soon eats through a Hessian crucible. Thus we obtain all the silver, and the process is simple and easily performed; the heat necessary is too great for an iron or copper pot, and if the assay is well regulated, the amount of metal produced may by proper attention be considerably diminished.

The first method, that is, the assay with metallic lead in the muffle of the cupel furnace, is the most correct, and whenever any doubt exists, it may be resorted to as a final proof of a good assay. It can be applied in all cases where the presence of the precious metals is expected; it is a quick operation, causing but little labour to perform it on an extensive *scale. It is* the best method of assaying. The use of borax facilitates the operation in some measure, but when more than $\frac{1}{16}$ or $\frac{3}{32}$ of the ore is employed, the assay works slower and is not quite correct.

When metallic ores are exposed to heat and such re-agents as develope the metal, it is commonly called smelting, in contradistinction from the mere application of heat, which causes ore to become fluid, and is called melting. Smelting is a chemical operation, conducted on the same principles as a moist assay in the laboratory; excepting that we produce in this case but one valuable substance, the metal, and consider the slags as accidental results. The slags require the closest attention of the metallurgist, because if they are of the right composition, the metal will invariably appear in the proper form. In all cases of smelting, it is an essential condition that the degree of heat should be so high as to cause all substances to become perfectly fluid. In principle there is no difference—if we mix two fluids, or a fluid and a solid, which show different affinities for the matter in solution—if the fluidity is produced by matter which is fluid at common temperatures, or only at a high heat. If oxide of iron is put into a watery solution of the sulphuret of potassium, the result is sulphuret of iron and potash; if the sulphuret of potassium is melted by heat, and we put into the fluid the oxide of iron, we have the same result; sulphuret of iron and potash are in the hot, melted mass. If some potash or soda is put into a red-hot solution of silicate of lead, metallic lead is precipitated, because the potash has more affinity for silex than oxide of lead. When into a fluid silicate of iron, carbon, lime, or other bases, or an oxide of metal is brought, such as manganese, which has more affinity for silex than iron—it will deprive the silex of its iron, and precipitate the latter in its metallic state. The manipulation in the laboratory differs from the manner of operation in metallurgy, but we recognize in both the same laws of affinity.

In almost all smelting operations the object is to produce a certain metal, and to form of all the other metals oxides and slags. This operation is greatly facilitated by the fact that most of the metals are specifically heavier than their melted oxides, or than these oxides in combination with silex or other acids; and if slags and metal are actually rendered perfectly fluid, they will separate in consequence of their want of affinity, and their difference in specific gravity. This case is like that of common fluids. Water and oil may be mixed, but they soon separate, the oil floating in a distinct stratum on the surface of the water. Metallic lead and oxide of lead, or a silicate of the oxide of lead, or any other silicate, may be mixed when in a rigid state, and they do not separate; but when both are fluid or melted, metal and slag soon separate, the former being found below the latter. When lead, iron, and slag are melted together, we obtain lead for the lowest stratum, iron on that, and the slag above the iron. The specific gravity of each indicates their relative positions. In all smelting operations we obtain at least two separate strata, often three, and in some instances four, of different substances.

Metals.—These are contained in the ores, in most cases, as compounds; and if it is the object to separate them, we are to put such matter in contact with them as will deprive the metal of its compound. If a silicate of iron is melted, we do not precipitate iron by *adding carbonate* of soda or caustic lime to the fluid mass; this addition merely increases the fluidity of the slag without producing any metal. But if we add sodium, the oxide of iron will be deprived of its oxygen and form metal. Carbon has more affinity for oxygen than metal in the high heat of a melted silicate; if therefore we add carbon to the melted silicate of iron, some iron is produced in all cases. When in this instance sufficient iron is precipitated to deprive the slag of its fluidity, no metal is formed, however much carbon we may add; for the metal requires a slimy, glassy coating to protect it against the influence of oxygen. When exposed in small particles to the influence of oxygen, almost all metals burn more readily than carbon,—gold, the platinum metals, and silver, in some measure excepted. If therefore we desire to obtain metal, we must produce a slag which protects it and at the same time admits of its coagulation. If to fluid silicate of iron, potash or soda is added, and at the same time carbon, metallic iron will be produced, because the slag retains its fusibility by this addition; but when so much iron is precipitated as to render the slag not sufficiently fusible to cover the metal with a slimy coating, the presence of potash even will not prevent the iron from burning. Carbon in any form has a strong affinity for oxygen, and precipitates all the metals from oxidized compounds; but it must never be forgotten that metal in fine particles has more affinity for oxygen than carbon, no matter how high or low the temperature may be. It is evident from this that no metallurgical operation can be perfect until the heat is sufficient to melt both metal and slag. Some metals are extremely refractory and do not melt in any heat we can produce by means of carbon; such are platinum, chromium, iron, and others. In these cases we combine the metal with other substances which cause it to be fusible. Platinum is fusible in combination with lead; chromium in combination with arsenic; and iron in connection with carbon, phosphorus, arsenic, sulphur, and a number of alloys, is fusible, while by itself it cannot be melted. By these means we may precipitate and melt a metal which without such an addition would not melt. Silver and gold, if pure, do not melt very readily, and they evaporate at a heat only little higher than their melting point; it is therefore necessary to combine these metals with one that is more fluid, in order not to lose much of them. These considerations will lead the metallurgist to employ the proper means for obtaining the metal in a fluid state.

Slags.—As was remarked above, the composition of the slags determines the quality and quantity of the metal produced; and if considerations of economy did not interfere with the application of fluxes, other than natural ones, there would be no limit to the production of metals in quality and quantity. Slags are glasses compounded of substances which melt at a particular degree of heat for each definite composition. The study of the nature of slags forms the science of smelting; the metals follow of course when the fluxes are correctly compounded. It is not always the case that metals are obtained at first melting; some ores are first converted into matt, such as copper, then roasted, and the metal extracted by a series of roastings and smeltings. These operations, all made with a view of compounding a proper slag, complicate the smelting process so far that we distinguish in them oxidizing, melting, reducing or smelting, and refining. Each of these operations involves different principles, and we shall for these reasons speak of them before treating of the composition of slags.

Oxidation.—When sulphurets which cannot easily be desulphuretted by roasting, such as copper pyrites, are to be smelted, we either melt and roast by atmospheric air, or by the addition of oxides to the melted mass. When iron pyrites is melted together with the oxide of iron, a large portion of sulphur is evaporated in the form of sulphurous acid, and the remaining sulphuret of iron when exposed to the atmosphere is easily decomposed; part of it is converted into green vitriol, and the rest forms peroxide of iron.

The oxidizing operation is facilitated either with or without the assistance of atmospheric air, by all the highest oxides of metals, such as oxide of lead, peroxide of iron, black manganese, saltpetre, common salt, silex, water, and in fact any substance which gives off oxygen, or facilitates an absorption of atmospheric oxygen. Oxidizing smeltings are often far cheaper than roasting, and this is an object which well deserves the attention of metallurgists, more especially as it requires less labour and fuel to oxidize sulphurets in this manner, than by roasting, pounding, and washing. In the large operation we cannot employ litharge or saltpetre as a means of oxidation, because they are too expensive; but instead of them we use coarse silex, gypsum, salt, oxide of iron, or black manganese. In this case it is all-sufficient to mix the mineral with such substances as cause it to divide and offer more surface to the atmospheric air. The substances used for oxidation are dependent entirely on the quality of ore, and the mode of operation in the subsequent reducing process. If we roast galena with fine silex, which of course will soon liberate the lead from sulphur, not much metal can be obtained, because the slag formed by the oxide of lead and silex is so far infusible as to admit of no separation of the lead from it. But if the silex is used in large grains, which leaves sufficient spaces for the globule of melted metal, we may obtain as much metal in the presence of an excess of siliceous matter as in a perfectly fluid and alkaline slag. This of course excludes the possibility of a fusible slag, but it serves as an illustration of the principles involved in smelting. Any other substance than silex may serve the same purpose, provided it has no affinity for that which is to be removed by evaporation, and is sufficiently refractory to resist melting with the oxide produced by that metal which is to be oxidized. The most extensive application of oxidizing melting is made in smelting sulphurets of copper in reverberatory furnaces. In this case iron must be always present; this metal combines with sulphur more readily than copper, but it also parts with it more readily, when exposed to the effect of the oxygen of the atmosphere: the oxides of iron thus formed absorb sulphur from copper as long as any is present; and when all the sulphur is expended the iron forces the copper from its combinations with silex. Common salt is profitably employed for oxidation; all chlorides are volatile, and so is common salt; but if the quantity used is small, and it serves as a mere assistant in the operation, it will long resist the influence of heat, particularly in alkaline slags. In the presence of clay or lime, common salt will bear a high heat for many hours without scarcely evaporating. Salt to the amount of one or two per cent.

in the slag will resist the heat of a puddling-furnace for 24 hours, without being expelled. Sulphates act like chlorides, but it is necessary that no carbon should be present; the latter will decompose any sulphate in a melted condition, and it ceases then to act as an oxidizing agent. The presence of carbon facilitates the evaporation of chlorides also, but that which remains is still a powerful means of oxidation.

The oxidizing operation by smelting is always imperfect, that is, all the volatile substances, such as sulphur, arsenic, antimony, and phosphorus, are never removed entirely, and the metal is obtained gradually. The presence of the volatile matter serves in part to liquefy the slags. By these means, copper, lead, antimony and a few other metals may be obtained; but when it is an object to produce all the gold and silver contained in an ore, every particle of sulphur, &c. should be removed, and the mineral brought to the highest state of oxidation, before subjecting it to the reducing operation with carbon.

Reducing.—The means employed for obtaining metals from oxides, and other compounds, are so extensive and varied, and the apparatus so well adapted for accomplishing the object in view, that speculations on this subject are the most interesting of all branches of industry to which intellect may be applied. Conducted on the principles developed by chemistry, the mineral may require water for solution or heat; but as the composition of minerals is extremely variable, the means employed are of course equally so. The heat ranges from the boiling point of water to the highest attainable. The means of reduction are, metals, and to some extent the oxides of the heavy metals, alkalies and alkaline earths, carbon, hydrogen, carburetted hydrogen, and a variety of other matter.

By Metals.—If we put into a fluid solution of sulphurets, arseniurets, or oxides, a metal which has more affinity for sulphur, oxygen, arsenic, &c., than one of the metals in solution, the latter is precipitated, and the first assumes its position in the fluid mass, provided it is soluble. If it is not soluble it will still absorb the substance for which it has most affinity from the metal, and float upon the reduced metal, provided the latter is heavier and both have little affinity for each other. This operation must be conducted with all the niceties of a chemical experiment. When sulphuret of lead or antimony is melted, and pure metallic iron is placed in contact with it, the iron will absorb the sulphur from these metals and produce them in their pure condition. Lead has little or no affinity for iron, the metal produced is therefore pure. Antimony combines readily with iron, and if the quantity of the latter is larger than merely to absorb the sulphur, it will combine with iron and form an alloy. In the first case it does no harm if more iron is used than is required, but in the latter it is injurious to the metal which is to be reduced. The quantity of the substance used for liberating metal from its combinations is here of equal importance as in chemistry, and the same laws are applied; the quantity increases the affinity. When a large quantity of iron is present in copper ores, we may succeed in obtaining almost all the copper; but when little iron is in the slag, the copper has such affinity for either volatile matter or silex, that a large per-centage remains in the slags, which can be recovered only by heavy expense. In all operations of this kind we are therefore to consider the affinities and also the amount of the mass.

By Oxides.—When a mixture of potash and soda is melted, and we add to it a sulphuret of a metal whose basis melts below the heat of the alkaline sulphuret, and whose sulphuret is not soluble in the alkali, we obtain a certain portion of the metal, and often the whole of it. Zinc blende, galena, and the sulphurets of the fusible metals, form pure metals which separate; but iron or copper pyrites form no metal, because they do not melt in that heat, and remain either as oxides or sulphurets in the solution. Sulphurets of gold, platinum, or silver, do not produce metals, but when lead is present a part of these metals may be obtained. The sulphurets of arsenic and tin do not form metals, because these combinations as well as their oxides are soluble in alkalies. The same law which is here applied to potash and soda is applicable to the alkaline earths, and metallic oxides when these form fluid slags. Lime will effectually reduce the sulphuret of any metal, but as the heat by which it melts is very high, we can produce only those metals which do not evaporate at that heat. If the vapours of the metal are equally valuable with the melted metal, such as quicksilver and zinc, we reduce sulphurets by the use of lime successfully. When lime is used to excess in reducing sulphuret of iron, the latter may be freed from sulphur almost entirely. In the same manner, protoxide or magnetic oxide of iron acts upon galena; if the iron predominates and becomes fluid at so low a heat as not to evaporate the lead, all the lead may be obtained. The application of these principles is extremely important in metallurgy, and it deserves more attention than is commonly paid to it. Oxides of metals cannot be reduced by other oxides, unless the higher oxidization of a newly formed oxide is more soluble than the previous one. When oxide of lead or of tin is cast into an alkaline silicate of iron, some metal is produced; this is not because the higher oxidization of iron causes the slag to be more fluid, but because some of the iron may be more highly oxidized without interfering with the fluidity of the cinder: the addition of some oxide of lead which remains, causes it to be more fluid, or at least retain its fluidity.

Carbon.—Of all the means at the disposal of the metallurgist, carbon is the most available for reduction. It is of little use in reducing chlorides, sulphurets, and arseniurets—for these metals are necessary: but as most minerals are in the form of oxides, and carbon is, in the high heat required, a strong agent in removing oxygen, it is generally applied. Hydrogen is also an effective means of reduction; but as its compound, water, oxidizes hot metal readily, and as the heat by which it operates is generally too low to melt the metal, its application is extremely limited. Hydrogen is employed in some cases, in its combinations with carbon, to reduce oxides, such as oxide of tin, or zinc; but it is then used to a very limited extent, such as the small quantity which is present in the coal employed, whether bituminous mineral coal or soft charcoal. This gas has in many cases a decided influence on the smelting operation, as we shall see; and it is mostly removed by charring that fuel which contains hydrogen to an injurious extent. Carbon is particularly suitable for the reduction of oxides in consequence of its volatile compounds with oxygen, and its harmless *combinations* with the metal produced.

The results of the deoxidizing operation, that is, carbonic acid, and carbonic oxide, are extremely volatile, and escape without any injury to the slags, or the metal produced. When carbon is brought in contact with oxidized ore, and there is no other oxygen present but that in the ore, it will be forced to combine with that. When a mixture of carbon and ore is exposed to fire, no combination between the ore and carbon can ensue, because both are rigid and the particles cannot move; and as motion is indispensable in any chemical operation, no combination between carbon and the oxygen of the ore could happen, unless one or the other was made fluid by heat. In the first place, there is always some air, particularly oxygen, in the pores of charred coal—also in the pores of ore; this oxygen is at liberty to move and will combine with carbon, and as carbon is sufficiently abundant the combination formed is carbonic oxide. This gas will combine with another portion of oxygen where it finds such at a sufficiently high heat; and inasmuch as the ore nearest to it is hot, the gas will absorb oxygen from the ore and escape in the form of carbonic acid. The ore thus deprived of oxygen produces metal. This explanation may serve in all those cases where the metals readily part with their oxygen, but it is not sufficient to explain the reduction of metals which have a strong affinity for oxygen and even melt with their oxides. For these reasons the refractory metals are smelted with fluxes, which cause the ores to become fluid, and in this manner they are brought in close contact with the coal. The use of fluxes is, therefore, not confined to the absorption of foreign matter: it is highly valuable in accelerating the smelting operation. For this reason we see the oxides of lead, bismuth, antimony, nickel, and cobalt, reduced very readily; because the oxides themselves, or mixed with fluxes, form fusible slags which readily flow over the carbon and cause a close contact between it and the oxygen. Tin, zinc, iron, chromium, and manganese, are not easily reduced, because their oxides are very refractory, and the first two metals evaporate in that heat at which carbonic acid is formed from their oxides: for these reasons it is necessary that soft charcoal or bituminous coal be used in their reduction. Neither the oxides of the other metals, nor the metals themselves, melt readily; but if we cause the oxides to become more fusible by adding fluxes, and the metals by alloying them with a substance which makes them fusible, we may produce either of these metals very readily. The reduction in most cases takes place previous to melting—and it is in fact not necessary that the ore should be melted before reduction ensues; but if it should be, it facilitates the formation of metal.

The doctrine that carbonic oxide is the agent in the process of reduction is not objectionable, so far as those metals are concerned which are not oxidized by carbonic acid, and which do not absorb carbon. This theory does not, therefore, apply generally. Some metals decompose carbonic acid—they cannot be reduced by it or in its presence; others again absorb carbon, which neither carbonic acid nor the carbonic oxide can afford: and it is necessary to adopt a hypothetical compound of carbon and oxygen in order to explain the carbonized state of some metals, such as iron, lead, manganese, and others. The combination of carbon and metals appears to be in most cases a *mere* mechanical mixture, and it cannot be assumed that the affinity of metals for carbon is so strong as to decompose carbonic oxide. We shall illustrate this subject by referring to a particular case in which carbon is of peculiar effect, namely, that of iron. When iron ore is smelted in a blast-furnace, it is found not only difficult, but almost impossible to manufacture gray iron from magnetic ore, when not roasted or oxidized previous to smelting. It is impossible to make gray iron by smelting silicates of any kind, such as forge cinders or puddling-furnace slag. If only the presence of carbonic oxide was required, these forms of iron ore ought to furnish gray iron as well as any other ore, for the ore is constantly in contact with that gas and with pure carbon also. We explain this by referring to the compact form of the ore. All the ores which are compact are reduced by the carbon acting on the exterior particles of the lumps. The metal formed being fluid, runs off by accumulating into a body, which is in that form not accessible to carbon, or capable of forming any compound with other matter, because the points of attraction and contact are wanting. No matter, however, what the rationale of this phenomenon may be, the fact is generally known. Porous iron ores—spongy hydrates—are the most suitable to produce gray iron; in fact, they produce it as a necessary consequence of their form. If the latter was not the cause, this ore would be as little suited to form gray iron as any other, for it is of the same composition as specular ore, containing generally, however, more impurities than the latter; still it is very difficult to make gray iron of specular ore, and in fact of every kind of compact ore, no matter what may be its composition. Compact ore may be either perfectly pure or very impure; neither condition renders it suitable to form gray iron. If iron, or its compounds, are in a porous condition, there is not the slightest difficulty in combining them with carbon. We conclude therefore that carbon penetrates into the pores of ore and metal in a solid form; for it is evident that spaces are required to bring particles of carbon in contact with particles of ore, or the compact ores would form gray iron quite as well as porous ones.

If porosity of the ore or metal is an essential condition of carbonizing it, then it is evident that carbonic oxide gas cannot have the power of conveying solid carbon to the metal, for that gas will penetrate less porous bodies than iron ores of a compact form. When carbonic oxide gas is the agent, it will carbonize iron wherever it finds it in a proper condition; for if it is fluid, all the requisites of combination are presented. Still, we know by experience that pure carbonic oxide will not carbonize iron in the converting box of the steel manufacturer; it requires the immediate contact of solid carbon and solid iron to form a carburet. Iron may be carbonized and decarbonized when in a fluid state, but the operation is extremely slow, and cannot be supposed to happen in a blast-furnace where the melted metal sinks down into the hearth rapidly. We assume, therefore, which assumption is supported by experiment, that carbon in a solid form is deposited in the pores of the ore before it is melted, and that in melting, the cohesion of the metal brings the carbon into so close contact with the metal as to force it into its pores and effect a union. The carbonizing of iron in the converting box presents no objection to this theory, as we shall see hereafter.

When carbon is present in the ore before it is melted, how does it get there? how is it deposited in that form? Carbonic oxide cannot deposit carbon, for it finds abundance of oxygen in the ore to combine with, and will naturally form carbonic acid. But supposing carbonic oxide was decomposed in the pores of the ore, the result must be carbonic acid in all cases, which is evidently not the fact in the blast-furnace, for we find the latter filled with carbonic oxide nearly to its top; at least so far down as any carbonic acid is formed, no perceptible alteration is observed in the ore. From the lowest point where carbonic acid ceases, downwards, the effect of carbon commences, the cementation of ore goes on, and still there is little or no carbonic acid gas in the furnace. A cold plate is blackened when held over the flame of a clear-burning candle; solid carbon is deposited from the gaseous solution of the flame. It may be objected to this parallel example, that in the flame of oil and of fat there is an abundance of hydrogen, which holds carbon in solution. May not carbonic oxide have a similar effect on carbon as hydrogen when at a high heat? The solvent power of this gas for carbon may be very faint, existing only at a high heat, and being destroyed at a diminution of that heat. The operations of the blast-furnace, the mode in which the blast is introduced, and the appearance of the ore and gas in the furnace, confirm this theory of carbonising iron.

Alloys.—If we adopt the foregoing theory for combining carbon with metals, we obtain at once a clear, comprehensive view of the conditions under which alloys and the various combinations of metals and other substances may be formed; and as these combinations are of the utmost importance to the *metallurgist*, they are well worth the trouble of a close examination. It is not only the combination but also the separation of such combinations, which are of interest. The above demonstration shows at once under what conditions alloys may be formed, even if the affinities and other relations are averse to any combination. We may melt pure iron and arsenic metal together as long as we please, no union of the two can be effected; the arsenic evaporates before the iron is sufficiently hot for its combination. But if we heat fine iron filings and arsenious acid with carbon, at first gently, we may melt both together very readily, and obtain an extremely fusible arseniuret of iron. This operation is still more easily performed if we heat borings of gray cast iron and arsenious acid together. And this alloy may be produced in any form or compound which we choose, if we mix arsenious acid, oxide of iron, and carbon in grains together, and bring the various particles in close contact before heating, by moistening the mixture with a weak solution of potash or soda, and drying the whole before smelting. A very slight heat will melt this alloy, and all the iron in the mixture is readily obtained under a cover of carbon. The most refractory metals may thus be made fusible, and obtained from their ores, and the facility with which they are produced depends on the arrangement which we have made before smelting is commenced. Chromium is very refractory, but if we mix its oxide with carbon and a little phosphoric acid, and moisten the mixture with an alkaline solution, so as to bring all the ingredients into close contact before smelting, we obtain chromium at a low heat in a perfect button, which is of course adulterated by phosphorus. It is extremely tedious to reduce potash so as to obtain potassium in a pure form, but there is not the slightest difficulty in combining antimony with potassium to a large extent; and if it was an object to produce potassium on a large scale, some means may be devised to separate the two metals. These relations show distinctly by what means and modes combinations of metals and other substances, or metals among themselves, may be effected. If we had it in our power to form perfectly pure oxide of iron, and mix it with perfectly pure carbon, and exclude any other matter, such as silex, from coming in contact with the mixture, steel might thus be formed to perfection. But as one of the first conditions in thus producing steel is the absence of all other matter except pure carbon and pure oxide of iron, we may reasonably doubt the possibility of producing good steel by these means, because on a large scale neither oxide of iron nor carbon can be obtained sufficiently pure. It is therefore necessary to produce metallic iron in that form in which it has the least impurities,—that is, pure wrought iron,—and cement it in such a manner that other substances than those which are volatile cannot come in contact so as to penetrate its mass. When iron melts by excess of heat in the converting box, it is changed into impure cast iron, of which steel cannot be made; in this fluid state it absorbs so much silex from the charcoal as to form a brittle compound.

When metals are in intimate connection with other matter, they are in the best state to form new compounds. When an alloy is melted and mixed with another alloy, or a compound, the particles will combine according to their predisposition; elective affinity is quite as active here as in any chemical process performed under different circumstances.

When melted galena is passed over red-hot pure iron, metallic lead and sulphuret of iron is produced; and when fluid carburet of iron (gray cast iron) is poured into fluid litharge, iron and metallic lead are produced. When an alloy of lead and tin is mixed with melted iron, the latter will combine with the tin and separate the lead. Gray cast iron, mixed with a silicate of iron, will reduce so much of the oxide of iron as its carbon indicates; this operation is often accidentally performed in the puddling-furnace of the iron-works.

From these speculations it is easy to infer the great importance of the composition of the slags for the purity of the metals produced. In all smelting operations, slags must be formed in order to remove the impurities of the ore; and when carbon or any other substance is combined with the metal produced, and that may be retained in the cinder when the metal passes through it, in most cases the carbon, &c. will change places with some substance in the slag. The metal is thus adulterated with the substance taken from the slag. This subject is of extreme importance.

Separation by Weight.—In reducing metals from their ores, it must be the aim of the operator to form globules, and at the same time form such spaces through which they may descend. In a mixture of ore and carbon, if the latter is so fine as to prevent the descent of the metal, this may be perfectly reduced, and still no accumulation ensues: this happens particularly when an excess of carbon is used, and as this is inevitable in large operations, it is advantageous to select the coals in coarse parts. The larger these globules, the size of which is facilitated by *coarse carbon*, the faster their descent will be. When small globules reach a mass of fluid slag, and are too small to penetrate it, they will remain on its surface, and even may be suspended within the body of it. This phenomenon happens frequently at blast-furnaces;—it may be, at those for smelting lead, copper, or iron; a stiff slag will always retain metal in round grains, which is often found to amount to a considerable portion of all which is produced. If the slags are thrown away, this metal is entirely lost; but it may be recovered by pounding and washing the slags. At iron furnaces this loss amounts on an average to five per cent., often more: it is considerable at copper and lead furnaces, and in fact cannot be avoided in any smelting operation. The larger the globules of metal, the less are they liable to be retained by the slag. It is therefore disadvantageous to use too small coal, or form a stiff, tenacious slag.

Slags.—The form of slags, their fluidity and composition, is of so much importance to the metallurgist, that too much attention cannot be paid to this subject. We shall here confine our remarks to operations on a large scale. The substances of which slags are formed are chiefly silex, as the acid, and the metallic oxides, as bases or alkalies. Besides silex, we find, however, carbonic acid, chlorine, sulphuric acid, fluorine, phosphoric acid, and others in the slags; also sulphur and phosphorus. The alkalies are chiefly oxide of iron, the oxides of manganese, lead, and copper; the alkaline earths are clay, and such fixed alkalies as are brought into the mixture accidentally, either by the ore or by the fuel. The substances which are added to an ore, in order to separate the metal, are fluxes, of which the number is very limited, because considerations of omy compel the smelter to confine his selections small number of minerals and artificial ingre- ;s. The most common fluxes in use are lime- e, oxides of iron, and iron pyrites; siliceous or iginous slates and shales; clay; fluor-spar; manganese; common salt; and a few other tances.

usibility of Slags.—The degree of heat at which melt is very different for different composi- , and ranges, as remarked before, between the ng point of water and the highest attainable

hen it is the object to liquefy silex, the only ts by which to do it effectually are potash, , lime, oxide of lead, oxide of iron, and man- se. The presence of phosphoric acid or chlo- will not add to the capacity of these sub- ;es for dissolving silex, but as their combina- with metals are very fusible, they increase the ity of the slag: this alludes particularly to those which contain an abundance of metallic oxides. nnot therefore be the object to dissolve silex ny such acid, but to cause the basis to be more , and by that means compel the imperfectly lved silex to float more freely in the slags. application of other acids than silex, is limited w heats only, because they generally evaporate 'e certain combinations or reductions can be ;ed. Protoxide of iron is the substance most rally used for dissolving silex, not because of its ility, but because it can be obtained abundantly ery place, its cheapness being the cause of its ral use. Lime is next in importance to oxide of as a flux, but it does not form quite as fusible a with *silex* as iron or manganese; and metals which cannot bear a high heat cannot be fluxed by means of lime, magnesia, clay, and similar substances. The fusibility of sulphurets is in many instances resorted to as a means to form slags, but these cannot dissolve silex, and so far as the latter substance is removed by sulphurets, it is only by its being suspended in the fluid mass and rendered more fluid. Yet all these heterogeneous substances may be united in a slag and form a perfectly fluid mass; and it is an important fact to be known in metallurgical operations, that all compounds are more fusible than single elements, and all slags increase in fusibility as their number of elements increase. This relates to metals and alloys as well as to slags; and on this principle all operations must be conducted.

Lime and silex are not very easily melted: clay and silex show hardly any signs of melting; but lime, clay, and silex melt very readily together. Protoxide of iron and silex form a fusible slag, but when manganese, or lime, or soda, or potash is added, the fusibility of the slag is remarkably augmented. In all cases the fusibility of a compound of various slags is greater than the mean fusibility of the whole, when considered as melted by themselves. If a compound of lime and silex melts at 3000°, that of protoxide of iron and silex at 2000°, and that of a silicate of oxide of lead at 1000°, the mean heat of the three, by which they will melt when mixed together, is not $\frac{3000+2000+1000}{3} = 2000^\circ$, as their various degrees indicate, but it may be only 1500°, and in this case even lower than that. The greater the number of elements in a slag, the more fusible it becomes; it is therefore of the utmost *importance* in all smelting operations to multiply the kind of ores: this produces fusible slags and fusible metals. In smelting iron, copper, lead, and all other metals, these rules are very well known by experienced smelters, and attended to; still they are not so much observed at the furnaces as they should be. As foreign matter has a decided influence upon some metals, it requires extreme caution in the selection of fluxes for certain kinds of metal. A flux which contains phosphorus will not in the least interfere with the quality of lead, but does great harm to iron, less to copper, and none at all to silver or gold. The presence of arsenic in an iron ore causes cast iron to be very short and hard, but it has a beneficial influence in making wrought iron: this substance cannot be removed from silver but by a tedious refining process: it acts in the same manner with lead. Sulphur is very injurious to iron and copper, but has no effect whatever on lead; silver and gold are more or less affected by its presence. The selection of fluxes must be therefore made with some discrimination and judgment in these respects.

Slags should be as fusible as the metal which is to be smelted with their assistance. If they are more refractory than the metal, the slag causes it to assume a heat by which more or less of it is evaporated. The slags must be so compounded that the flux which is added to the ore has more affinity for the foreign matter than for the oxide of the metal, or the metal itself which is to be produced. In the mean time the new compound formed by the flux and the foreign matter ought to be more fusible than the metal, so as to float down before the metal is perfectly melted. In some instances, namely, in those where the metal is to be carbonized, this rule is not applicable, for it invariably removes the carbon from the metal. By means of such a fluid slag any kind of impurities may be removed from the metal when properly attended to. Another advantage of a fusible slag is the saving of fuel, for in this instance there is no need of raising the heat beyond the melting point of the metal.

Learned men have demonstrated that certain quantities of particular matter are required to form the most fusible compound. There is no doubt that certain laws regulate the formation of slags, which have evidently a strong bearing upon the results of metallurgical operations, but in smelting we cannot pretend to the niceties of the laboratory, and it is quite sufficient if we approach the laws strictly regulating this subject. When a slag is tough and tenacious it requires an alkali to make it more fluid; and if it is hard and brittle, inclined to chill, it requires an acid to flux it. In many cases the addition of other slags, so as to increase the quantity, causes the slag to be more fusible, and affords at the same time a protection to the metal. We will here allude to a few facts which indicate the importance of composition.

A slag taken from a blast-furnace for smelting iron, and which was composed of 50 silex, 17 alumina, 30 lime, and 3 protoxide of iron, melted by 2576°; but when the ingredients forming this slag were put together, finely powdered and mixed, and then exposed to heat, it required 3400° to form a slag of them. This shows how much more heat is required to melt a crude mixture than to melt a compound in which the particles are already arranged. It shows at the same time, that when the flux or a part of the flux is soluble in water, it ought to be dissolved so as to bring it and the ore in close contact before exposing them to the influence of heat. Another composition of iron slags, which consisted of 58 silex, 6 clay, 2 protoxide of iron, 2 protoxide of manganese, 10 magnesia, and 22 lime, required the same heat as above for softening it, namely, 3400°. The heat by which it was kept in fusion was also similar to the above, namely, 2600°. Slag from a lead furnace, which was held in a fluid condition by a heat of 2400°, required 2650° for softening the ingredients of its composition. That slag was composed of 36·5 silex, 40·5 protoxide of iron, 8·5 alumina, 4· lime, 3· magnesia, 7·5 oxide of lead. A slag from a copper smelting furnace, for crude copper, contained 32·7 silex, 60·3 protoxide of iron, 7· alumina: this was held in a fluid state by 2400°, and required 2700° for melting the ingredients of which it was composed. We see here that the smaller the number of elements, the less readily a mixture melts.

In order to compare the above degrees of heat by which the slags are melted and kept in solution, with the degrees of heat by which metals melt, we annex the following: gold melts by 2000°, silver by 1870°, lead 630°, cast iron 2500° to 3000°, and platina 4580°.

General Reflections on Smelting.—In order to obtain a clear insight into smelting operations, it is necessary to analyze each process, and each part of that process, and observe what influence certain causes produce upon the metal. Here, as everywhere, it is difficult to reason from effect to cause, and therefore we follow the other way of arriving at conclusions. And if we apply the well-known laws of chemistry, with due regard to temperature, we shall hardly ever fail of coming to correct conclusions in our experiments. Of the metals, copper has the strongest affinity for sulphur; then follow iron, tin, zinc, lead, silver, antimony, arsenic. As shown here, copper has a stronger affinity for sulphur than iron, and still copper is desulphuretted by iron, simply because of the mass of iron present: if the latter does not predominate, sulphur cannot be removed from copper by iron. This is no exception to the law for disengaging sulphur, for it is very well known that affinity is increased by mass. The alkaline earths and fixed alkalies have still more affinity for sulphur than these metals; and still they cannot remove the sulphur from most of these metals. Sulphurets of zinc, copper, or iron, cannot be decomposed by melted potash, at least no metal is produced to any extent: galena may be reduced entirely by it. The reason is, that metallic lead is more fusible than its sulphuret, and will separate at a lower heat than will melt the latter in potash. Sulphuret of copper, or iron, does not dissolve in potash. The latter absorbs some of the sulphur, but still leaves the metals with so much remaining as not to form pure metal. If the copper or iron were more fusible than the sulphuret suspended in the potash, it would coagulate, form globules, and separate in the metallic state. Some metals are not formed of sulphurets, even if an abundance of alkali is present, until carbon is brought in contact with them. Of this kind are lead, copper, and some others. Lime forms sulphates of lead, and lime of galena, and only a small portion of metal is separated; but if carbon is added sufficient to decompose these sulphates, nearly all the metal may be obtained from its sulphuret. In some instances the fusibility of two united substances is resorted to in order to dissolve the one only. Sulphurets are not soluble in chlorides, neither are silicates, phosphates, or borates, and still a silicate with some chlorides is extremely fluid: a sulphuret may be perfectly mixed with chloride in the heat of a grate-fire; but as soon as the mass is cooled and water poured on, both separate. The cause is here obvious: sulphurets and chlorides are both soluble in heat, but not in water, in which only the latter is dissolved; and as no affinity exists between the two, both separate very readily. Still this compound performs in its smelted condition all the services of a slag. Carbonate of soda is no solvent for any sulphuret; it will melt, and the sulphuret will melt; both may be mixed together, but no decomposition ensues; but if carbon is introduced, so as to decompose the carbonic acid and liberate the caustic soda, it will absorb sulphur and produce metal in many cases, provided the metal is fusible in the heat which is applied. Copper may be reduced by these means. Iron cannot be melted, at least but very imperfectly, under a cover of potash or soda, because these substances will evaporate before the metal is melted. If carbon or sulphur is present in the iron, we may succeed somewhat better, but still imperfectly. If, however, a phosphate is present, either in the iron or in the flux, and also carbon sufficient to reduce the phosphate, iron may be melted easily under a cover of potash or soda. The metal, of course, which is the result of this operation, is very brittle, and a phosphuret, but it is chiefly iron. There is not the slightest difficulty in removing any quantity of impurities from a metal by means of matter which has more affinity for these substances than the metal itself. This implies always the condition that the metal should be fusible at the same degree of heat, or nearly, at which the slag is fusible; also that it should not evaporate by that heat.

Sublimation.—Metals which are very volatile cannot be advantageously smelted; they are distilled, and in some cases sublimation is resorted to. There is not the slightest difficulty in smelting zinc, under a cover of carbonate of soda and potash, with carbon. But such a flux is expensive; and when not closely attended to while fluid, the loss is greater than the value of the metal obtained. It is for these reasons found to be cheaper to mix the oxide or carbonate of zinc with carbon, and distil it; or to mix the zinc blende with iron and perform the same operation. The heat applied in these processes is by far higher than it is in smelting, and may cause the use of ten times as much fuel; still it is asserted that distillation is cheaper than smelting. Mercury is frequently produced by a simple sublimation, without the addition of flux or coal; so also is arsenic. But in most instances, carbon and such substances as decompose the ore are added to it.

Refining.—Refining gold and silver is done in large or small reverberatory furnaces, of which the bottom forms a cupel. Copper or lead is refined in reverberatories by melting, and the addition of fluxes. Tin is purified in reverberatory furnaces, and also in iron pots, being stirred by wood so as to oxidize its impurities. Zinc is refined in the same manner and by the same means. Iron is refined in charcoal forges, in run-out fires, in reverberatories, and in puddling and reheating furnaces.

Liquefaction.—This is a delicate operation, but it is of great utility. Bismuth is obtained by liquefaction. If the ore of this metal is heated with proper fluxes and in a proper apparatus, to a degree of heat which will melt the bismuth only, it will flow out from the ore, and form metal without the rocky and foreign matter being converted into a fusible slag. Antimony may be obtained by the same means, and in fact every kind of metal, provided the remains of the ore do not melt partially, so as to enclose grains of metal in a refractory, pasty cinder. As a mode of refining, it is chiefly used in separating silver from copper. When 11 parts of lead are melted with 3 parts of argentiferous copper, and this alloy is cooled slowly, the lead and silver may be made to flow out from the copper and lead; and the fluid lead thus obtained contains all the silver. The mode of operation in this case is generally to melt lead and copper perfectly, then cool it slowly. The copper and lead alloy, being the most refractory of the compound, will crystallize first, and the silver and lead last. When this combination of lead and silver, and the combination of lead and copper, is heated in a proper apparatus, the first will flow out at a certain heat and leave the other, which remains as a skeleton of the form of the whole body of alloy. Impure tin is refined on the same principle: when a pig of tin is laid on the highest part of the sloping hearth of a reverberatory furnace, and gently heated, the pure tin flows out first, and leaves behind a skeleton of iron, copper, and other metals, which do not melt at a low heat, and which are removed. This principle may be applied for the separation of metals by filtration: when, for instance, alloy is brought upon a body of sand, bone-ashes, lime, or similar matter, and melted, the moist fluid of the *metals in the alloy* will flow out first, pass through the sand, and a skeleton of the refractory metals will remain.

Crystallization.—Most of the metals crystallize readily; all of them crystallize by proper treatment. Antimony and iron are particularly distinguished for their power of crystallization. The alloys of metals are not so much inclined to form regular bodies, at least not at the same degree of heat: for these reasons alloys may be separated from the pure metal. The fluid metals act here on the same principle as a salt dissolved in water. This property of metals and alloys has led to a valuable refining process for silver. When argentiferous lead is melted and then slowly cooled, the pure lead will sooner crystallize than the alloy of silver and lead, and a part of the pure lead may be gradually removed by a skimmer, or drainer. No perfect separation ensues here, for the coagulated lead still contains silver, and the richer the alloy, the more silver is contained in the crystallized lead. Still, metal which contains but 10 ounces of silver in a ton of lead may be concentrated with little expense, to lead of 30 ounces of silver per ton. When these principles are intelligently applied, much may be expected of them in the way of refining metals.

Table of Squares, Cubes, and Fourth Power of Numbers.

Root.	Square.	Cube.	4th Power.	Root.	Square.	Cube.	4th Power.
1	1	1	1	7	49	343	2401
·1	1·21	1·331	1·4641	·1	50·41	357·911	2541·1681
·2	1·44	1·728	2·0736	·2	51·84	373·248	2687·3856
·3	1·69	2·197	2·8561	·3	53·29	389·017	2839·8241
·4	1·96	2·744	3·8416	·4	54·76	405·224	2998·6576
·5	2·25	3·375	5·0625	·5	56·25	421·875	3163·8625
·6	2·56	4·096	6·5536	·6	57·76	438·976	3346·2176
·7	2·89	4·913	8·3521	·7	59·29	456·533	3515·3041
·8	3·24	5·832	10·5876	·8	60·84	474·552	3701·4756
·9	3·61	6·859	13·0321	·9	62·41	493·039	3895·0081
2	4	8	16	8	64	512	4096
·1	4·41	9·261	19·4481	·1	65·61	531·441	4304·6721
·2	4·84	10·648	23·4256	·2	67·24	551·368	4521·2176
·3	5·29	12·167	27·8841	·3	68·89	571·787	4745·8221
·4	5·76	13·824	33·1776	·4	70·56	592·704	4979·5836
·5	6·25	15·625	39·0625	·5	72·25	614·125	5220·0625
·6	6·76	17·576	45·6976	·6	73·96	636·056	5470·0816
·7	7·29	19·683	53·1441	·7	75·69	658·503	5728·9761
·8	7·84	21·952	61·4656	·8	77·44	681·472	5996·9536
·9	8·41	24·389	70·7281	·9	79·21	704·969	6274·2141
3	9	27	81	9	81	729	6561
·1	9·61	29·791	92·3521	·1	82·81	753·571	6857·4961
·2	10·24	32·768	104·8576	·2	84·64	778·688	7173·9296
·3	10·89	35·937	118·5921	·3	86·49	804·357	7479·5201
·4	11·56	39·304	133·6336	·4	88·36	830·584	7807·4896
·5	12·25	42·875	150·0625	·5	90·25	857·375	8075·0525
·6	12·96	46·656	167·9616	·6	92·16	884·736	8493·6656
·7	13·69	50·653	187·4161	·7	94·09	912·673	8751·9281
·8	14·44	54·872	208·5136	·8	96·04	941·192	9231·6816
·9	15·21	59·319	231·3441	·9	98·01	970·299	9308·9601
4	16	64	256	10	100	1000	10000
·1	16·81	68·921	282·5761	·1	102·01	1030·301	10406·0401
·2	17·64	74·088	311·1696	·2	104·04	1061·208	10624·3216
·3	18·49	79·507	341·8801	·3	106·09	1092·727	11255·0881
·4	19·36	85·184	374·8096	·4	108·16	1124·864	11698·5856
·5	20·25	91·125	410·0625	·5	110·25	1157·625	12155·0625
·6	21·16	97·336	447·7456	·6	112·36	1191·016	12624·7696
·7	22·09	103·823	487·9681	·7	114·49	1225·043	13107·9601
·8	23·04	110·592	530·8416	·8	116·64	1259·712	13604·8896
·9	24·01	117·649	576·4801	·9	118·81	1295·029	14115·8161
5	25	125	625	11	121	1331	14641
·1	26·01	132·651	676·5201	·1	123·21	1367·631	15180·7041
·2	27·04	140·608	731·1616	·2	125·44	1404·928	15735·1936
·3	28·09	148·877	789·0481	·3	127·69	1442·897	16314·7361
·4	29·16	157·464	850·3056	·4	129·96	1481·544	16899·6016
·5	30·25	166·375	915·0625	·5	132·25	1520·875	17490·0625
·6	31·36	175·616	983·4496	·6	134·56	1560·896	18106·3936
·7	32·49	185·193	1055·6001	·7	136·89	1601·613	18749·9721
·8	33·64	195·112	1131·6496	·8	139·24	1643·032	19387·7776
·9	34·81	205·379	1211·7361	·9	141·61	1685·159	20153·3921
6	36	216	1296	12	144	1728	20736
·1	37·21	226·981	1384·5841	·1	146·41	1771·561	21345·8881
·2	38·44	238·328	1477·6336	·2	148·84	1815·848	22253·4556
·3	39·69	250·047	1575·2961	·3	151·29	1860·867	22898·6641
·4	40·96	262·144	1677·7216	·4	153·76	1906·624	23642·1376
·5	42·25	274·625	1785·0625	·5	156·25	1953·125	24414·0625
·6	43·56	287·496	1897·4736	·6	158·76	2000·376	25204·7376
·7	44·89	300·763	2015·1121	·7	161·29	2048·383	26011·6641
·8	46·24	314·432	2138·1376	·8	163·84	2097·152	26843·5456
·9	47·61	328·509	2266·7121	·9	166·41	2146·689	27692·388

It is by the second kind of lever that the greatest effect is obtained from any given amount of power; hence the propriety of the application of this principle to the working of force-pumps, and shearing of iron, as by the lever of a punching-press, &c.

Rule, second kind.—Divide the whole length of lever, or distance from power to fulcrum, by the distance from fulcrum to weight, and the quotient is the proportion of effect that the power is to the weight or resistance to be overcome.

Ex. Required the amount of effect or force produced by a power of 50lbs. on the ram of a Bramah's pump, the length of the lever being 3 feet, and distance from ram to fulcrum 4½ inches.

3 feet=36 inches, and $\frac{36}{4\cdot5}=8$, or the power and resistance are to each other as 8 to 1; hence $50\times8=400$ lbs. force upon the ram.

The lever on the safety-valve of a steam boiler is of the *third kind*, the action of the steam being the power, and the weight or spring-balance attached the resistance; but in such application the action of the lever's weight must also be taken into account, and may be simply ascertained by such means as represented in fig 2, plate D, where A is a *Salter's balance* attached to the lever by a light line, immediately at the point of pressure on the valve, and which, raised by hand or otherwise, will indicate the lever's action at that point.

This is perhaps the most frequent application of the third kind of lever to mechanical advantage, and that in which great nicety is required in estimation of effect: hence observe, as in other levers, there are three distinct points that require to be particularly *attended to;* namely, the *weight*, *fulcrum*, and *re-*

Fig. 1.

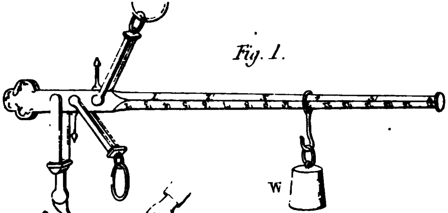
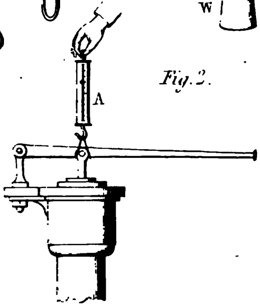
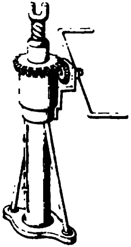
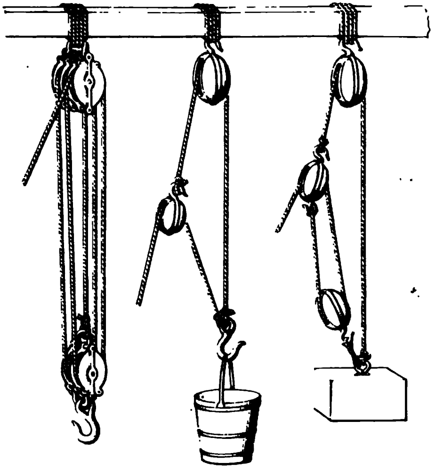


Fig. 2.



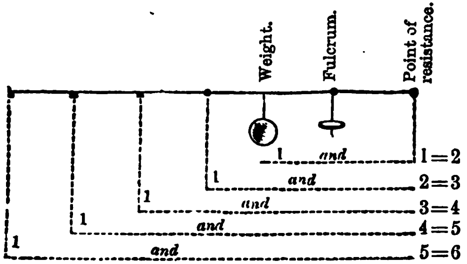




J. W. Lowry fc.

John Weale, 59 High Holborn 1853.

sistance, as shown in the annexed diagram to illustrate this particular case.



Thus, suppose the weight to be placed on any one of the divisions, it is still the same weight, or 1; but because of the principle of the lever, the resistance is increased equal to the number of times the weight is distant from the fulcrum; consequently the action of the lever tends to press down the valve equal the sum of the weight and resistance, or the number of times the weight is distant from the resistance.

2. THE WHEEL AND PINION, OR CRANE.

The mechanical advantage of the wheel and axle, or crane, is as the velocity of the weight to the velocity of the power; and being only a modification of the first kind of lever, it of course partakes of the same principles.

1. *To determine the amount of effective power produced from a given power by means of a crane with known peculiarities.*

Rule.—Multiply together the diameter of the circle described by the winch, or handle, and the number of revolutions of the pinion to 1 of the wheel; divide *the product by* the barrel's diameter in equal terms of dimensions, and the quotient is the effective power to 1 of exertive force.

Ex. Let there be a crane, the winch of which describes a circle of 30 inches in diameter; the pinion makes 8 revolutions for 1 of the wheel, and the barrel is 11 inches in diameter; required the effective power in principle, also the weight that 36lbs. would raise, friction not being taken into account.

$\frac{30 \times 8}{11}=21 \cdot 8$ to 1 of exertive force; and $21 \cdot 8 \times 36=784 \cdot 8$ lbs.

2. *Given any two parts of a crane, to find the third, that shall produce any required proportion of mechanical effect.*

Rule.—Multiply the two given parts together, and divide the product by the required proportion of effect; the quotient is the dimensions of the other parts in equal terms of unity.

Ex. Suppose that a crane is required, the ratio of power to effect being as 40 to 1, and that a wheel and pinion 11 to 1 is unavoidably compelled to be employed, also the throw of each handle to be 16 inches; what must be the barrel's diameter on which the rope or chain must coil?

$16 \times 2=32$ inches diameter described by the handle.

And $\frac{32 \times 11}{40}=8 \cdot 8$ inches, the barrel's diameter.

3. THE PULLEY.

The principle of the pulley, or more practically the block and tackle, is the distribution of weight on various points of support; the mechanical advantage derived depending entirely upon the flexibility and tension of the rope, and the number of pulleys or sheives in the lower or rising block: hence, by blocks and tackle of the usual kind, as shown in fig. 3, Pl. D, the power is to the weight as the number of cords attached to the lower block; whence the following rules.

1. Divide the weight to be raised by the number of cords leading *to*, *from*, or *attached* to the lower block; and the quotient is the power required to produce an equilibrium, provided friction did not exist.

2. Divide the weight to be raised by the power to be applied; the quotient is the number of sheives in, or cords attached to the rising block.

Ex. Required the power necessary to raise a weight of 3000 lbs. by a four and five-sheived block and tackle, the four being the moveable or rising block.

Necessarily there are nine cords leading to and from the rising block.

Consequently $\frac{3000}{9}=333$ lbs., the power required.

Ex. 2. I require to raise a weight of 1 ton 18 cwt., or 4256 lbs.; the amount of my power to effect this object being 500 lbs., what kind of block and tackle must I of necessity employ?

$\frac{4256}{500}=8{\cdot}51$ cords; of necessity there must be 4 sheives or 9 cords in the rising block.

As the effective power of the crane may, by additional wheels and pinions, be increased to any required extent, so may the pulley and tackle be similarly augmented by purchase upon purchase; two of the most useful of such applications being represented in figs. 3 and 4, Plate D, the first of which is known by the term *runner and tackle*, and the second by that of *Spanish burton.*

4. THE INCLINED PLANE.

The *inclined plane* is properly the second elementary power, and may be defined the lifting of a load by regular instalments. In principle it consists of any right line not coinciding with, but laying in a sloping direction to, that of the horizon; the standard of comparison of which commonly consists in referring the rise to so many parts in a certain length or distance, as 1 in 100, 1 in 200, &c., the first number representing the perpendicular height, and the latter the horizontal length in attaining such height, both numbers being of the same denomination, unless otherwise expressed; but it may be necessary to remark, that the inclination of a plane, the sine of inclination, the height per mile, or the height for any length, the ratio, &c., are all synonymous terms.

The advantage gained by the inclined plane, when the power acts in a parallel direction to the plane, is as the length to the height or angle of inclination: hence the rule. Divide the weight by the ratio of inclination, and the quotient equal the power that will just support that weight upon the plane. Or, multiply the weight by the height of the plane, and divide by the length,—the quotient is the power.

Ex. Required the power or equivalent weight capable of supporting a load of 350 lbs. upon a plane of 1 in 12, or 3 feet in height and 36 feet in length.

$$\frac{350}{12}=29{\cdot}16 \text{ lbs., or } \frac{350\times 3}{36}=29{\cdot}16 \text{ lbs. power, as before.}$$

Note.—The weight multiplied by the length of the base, and the product divided by the length of the incline, the quotient equal the pressure or downward weight upon the incline.

Table showing the Resistance opposed to the Motion of Carriages on different Inclinations of Ascending or Descending Planes, whatever part of the insistent weight they are drawn by.

Tens.		Hundreds.								
		100	200	300	400	500	600	700	800	900
		·01	·005	·00333	·0025	·002	·00167	·00143	·00125	·00111
10	·1	·00909	·00476	·00322	·00244	·00196	·00164	·00141	·00123	·0011
20	·05	·00833	·00454	·00312	·00238	·00192	·00161	·00139	·00122	·00109
30	·0333	·00769	·00435	·00303	·00232	·00189	·00159	·00137	·0012	·00107
40	·025	·00714	·00417	·00294	·00227	·00185	·00156	·00135	·00119	·00106
50	·02	·00667	·004	·00286	·00222	·00182	·00154	·00133	·00118	·00105
60	·0166	·00625	·00385	·00278	·00217	·00178	·00151	·00131	·00116	·00104
70	·0143	·00588	·0037	·0027	·00213	·00175	·00149	·0013	·00115	·00103
80	·0125	·00555	·00357	·00263	·00208	·00172	·00147	·00128	·00114	·00102
90	·0111	·00526	·00345	·00256	·00204	·00169	·00145	·00126	·00112	·00101

Vote.—Although this Table has been calculated particularly carriages on railway inclines, it may with equal propriety be lied to any other incline, the amount of traction on a level ng known.

Application of the preceding Table.

1. What weight will a tractive power of 150 lbs. draw up an incline of 1 in 340, the resistance on the level being estimated at $\frac{1}{240}$th part of the insistent weight?

In a line with 40 in the left-hand column and under 200 is.. ·00417
Also in the same line and under 300 is .... ·00294

Added together=·00711

Then $\frac{150}{\cdot00711}=21097$ lbs. weight drawn up the plane.

2. What weight would a force of 150 lbs. draw down the same plane, the friction on the level being the same as before?

Friction on the level=·00417
Gravity of the plane=·00294 subtract

=·00123

And $\frac{150}{\cdot00123}=121915$ lbs. weight drawn down the plane.

Example of incline when velocity is taken into account.

A power of 230 lbs., at a velocity of 75 feet per minute, is to be employed for moving weights up an inclined plane 12 feet in height and 163 feet in length, the least velocity of the weight to be 8 feet per minute; required the greatest weight that the power is equal to.

$$\frac{230\times75\times163}{12\times8}=\frac{2811750}{96}=29288 \text{ lbs., or } 13\cdot25 \text{ tons.}$$

TABLE OF INCLINED PLANES,

Showing the ascent or descent per yard, and the corresponding ascent or descent per chain, per mile; and also the ratio.

Per yard.		Per chain.	Per mile.	Ratio.	Per yard.		Per chain.	Per mile.	Ratio.
In parts of an in.	In decls. of an inch.	Inches.	Feet.	One in	In parts of an in.	In decls. of an inch.	Inches.	Feet.	One in
$\frac{1}{64}$	·0156	·344	2·29	2304	$\frac{7}{16}$	·4375	9·625	64·17	82
$\frac{1}{48}$	·0208	·458	3·06	1728	$\frac{1}{2}$	·5	11	73·33	72
$\frac{1}{32}$	·0312	·687	4·58	1152	$\frac{9}{16}$	·5625	12·375	82·5	64
$\frac{1}{24}$	·0417	·917	6·11	864	$\frac{7}{12}$	·5833	12·833	85·56	62
$\frac{1}{16}$	·0625	1·375	9·17	576	$\frac{3}{5}$	·6	13·2	88	60
$\frac{1}{12}$	·0833	1·833	12·22	432	$\frac{5}{8}$	·625	13·75	91·67	58
$\frac{1}{10}$	·1	2·2	14·67	360	$\frac{2}{3}$	·6667	14·667	97·78	54
$\frac{1}{8}$	·125	2·75	18·33	288	$\frac{11}{16}$	·6875	15·125	100·83	52
$\frac{1}{6}$	·1667	3·667	24·44	216	$\frac{7}{10}$	·7	15·4	102·67	51
$\frac{3}{16}$	·1875	4·125	27·50	192	$\frac{3}{4}$	·75	16·5	110	48
$\frac{1}{5}$	·2	4·4	29·33	180	$\frac{4}{5}$	·8	17·6	117·33	45
$\frac{1}{4}$	·25	5·5	36·67	144	$\frac{13}{16}$	·8125	17·875	119·17	44
$\frac{3}{10}$	·3	6·6	44	120	$\frac{5}{6}$	·8333	18·333	122·22	43
$\frac{5}{16}$	·3125	6·875	45·83	115	$\frac{7}{8}$	·875	19·25	128·33	41
$\frac{1}{3}$	·3333	7·333	48·89	108	$\frac{9}{10}$	·9	19·8	132	40
$\frac{3}{8}$	·375	8·25	55	96	$\frac{11}{12}$	·9167	20·167	134·44	39
$\frac{2}{5}$	·4	8·8	58·67	20	$\frac{15}{16}$	·9375	20·625	137·5	38
$\frac{5}{12}$	·4167	9·167	61·11	86	1	1	22	146·67	36

THE WEDGE.

The wedge is a double inclined plane, consequently its principles are the same: Hence when two bodies are forced asunder by means of the wedge in a direction parallel to its head,—Multiply the resisting power by half the thickness of the head or back of the wedge, and divide the product by the length of one of its inclined sides; the quotient is the force equal to the resistance.

Ex. The breadth of the back or head of a wedge being 3 inches, and its inclined sides each 10 inches, required the power necessary to act upon the wedge so as to separate two substances whose resisting force is equal to 150 lbs.

$$\frac{150 \times 1{\cdot}5}{10} = 22{\cdot}5 \text{ lbs.}$$

Note.—When only one of the bodies is moveable, the whole breadth of the wedge is taken for the multiplier.

THE SCREW.

The screw, in principle, is that of an inclined plane wound around a cylinder which generates a spiral of uniform inclination, each revolution producing a rise or traverse motion equal to the pitch of the screw, or distance between two consecutive threads,—the pitch being the height or angle of inclination, and the circumference the length of the plane when a lever is not applied; but the lever being a necessary qualification of the screw, the circle which it describes is taken, instead of the screw's circumference, as the length of the plane: hence the mechanical advantage is, as the circumference of the circle described by the lever where the power acts, is to the pitch of the screw, so is the force to the resistance in principle.

Ex. 1. Required the effective power obtained by a screw of ⅞ inch pitch, and moved by a force equal to 50 lbs. at the extremity of a lever 30 inches in length.

$$\frac{30 \times 2 \times 3{\cdot}1416 \times 50}{{\cdot}875} = 10760 \text{ lbs.}$$

Ex. 2. Required the power necessary to overcome a resistance equal to 7000 lbs. by a screw of 1¼ inch pitch, and moved by a lever 25 inches in length.

$$\frac{7000 \times 1{\cdot}25}{25 \times 2 \times 3{\cdot}1416} = 55{\cdot}73 \text{ lbs. power.}$$

In the case of a screw acting on the periphery of a toothed wheel, the power is to the resistance as the product of the circle's circumference described by the winch or lever, and radius of the wheel, to the product of the screw's pitch, and radius of the axle, or point whence the power is transmitted; but observe, that if the screw consist of more than one helix or thread, the apparent pitch must be increased so many times as there are threads in the screw. *Hence, to find what weight a given power will equipoise:*

Rule.—Multiply together the radius of the wheel, the length of the lever at which the power acts, the magnitude of the power, and the constant number 6·2832; divide the product by the radius of the axle into the pitch of the screw, and the quotient is the weight that the power is equal to.

Ex. What weight will be sustained in equilibrio by a power of 100 lbs. acting at the end of a lever 24 inches in length, the radius of the axle, or point whence the power is transmitted, being 8 inches, the radius of the wheel 14 inches, the screw consisting of a double thread, and the apparent pitch equal ⅝ of an inch?

$\frac{14 \times 24 \times 100 \times 6{\cdot}2832}{{\cdot}625 \times 2 \times 8} = 21111{\cdot}55$ lbs., or 9·4 tons, the power sustained.

Note.—It is estimated that about one-third more power must be added to overcome the friction of the screw when loaded, than is necessary to constitute a balance between power and weight.

OF CONTINUOUS CIRCULAR MOTION.

In mechanics, circular motion is transmitted by means of *wheels*, *drums*, or *pulleys*; and accordingly as the driving and driven are of equal or unequal diameters, so are equal or unequal velocities produced: hence the principle on which the following rules are founded.

1. WHEN TIME IS NOT TAKEN INTO ACCOUNT.

Rule.—Divide the greater diameter, or number of teeth, by the lesser diameter, or number of teeth, and the quotient is the number of revolutions the lesser will make for 1 of the greater.

Ex. How many revolutions will a pinion of 20 teeth make for 1 of a wheel with 125?

125÷20=6·25, or 6¼ revolutions.

Note.—Intermediate wheels of whatever diameters, so as to connect communication at any required distance apart, cause no variation of velocity more than otherwise would result were the first and last in immediate contact.

To find the number of revolutions of the last, to 1 *of the first, in a train of wheels and pinions.*

Rule.—Divide the product of all the teeth in the driving by the product of all the teeth in the driven, and the quotient equal the ratio of velocity required.

Ex. 1. Required the ratio of velocity of the last, to 1 of the first, in the following train of wheels and pinions; viz., *pinions driving,*—the first of which contains 10 teeth, the second 15, and third 18;—*wheels driven,*—first 15 teeth, second 25, and third 32.

$\frac{10 \times 15 \times 18}{15 \times 25 \times 32} = \cdot 225$ of a revolution the wheel will make to 1 of the pinion.

Ex. 2. A wheel of 42 teeth giving motion to one of 12, on which shaft is a pulley of 21 inches diameter, driving one of 6; required the number of revolutions of the last pulley to one of the first wheel.

$$\frac{42 \times 21}{12 \times 6} = 12 \cdot 25, \text{ or } 12\tfrac{1}{4} \text{ revolutions.}$$

Note.—Where increase or decrease of velocity is required to be communicated by wheel-work, it has been demonstrated that the number of teeth on each pinion should not be less than 1 to 6 of its wheel, unless there be some other important reason for a higher ratio.

2. WHEN TIME MUST BE REGARDED.

Rule.—Multiply the diameter, or number of teeth in the driver, by its velocity in any given time, and divide the product by the required velocity of the driven; the quotient equal the number of teeth, or diameter of the driven, to produce the velocity required.

Ex. 1. If a wheel containing 84 teeth makes 20 revolutions per minute, how many must another contain to work in contact, and make 60 revolutions in the same time?

$$\frac{84 \times 20}{60} = 28 \text{ teeth.}$$

Ex. 2. From a shaft making 45 revolutions per minute, and with a pinion 9 inches diameter at the pitch line, I wish to transmit motion at 15 revolutions per minute; what at the pitch line must be the diameter of the wheel?

$$\frac{45\times 9}{15}=27 \text{ inches.}$$

Ex. 3. Required the diameter of a pulley to make 16 revolutions in the same time as one of 24 inches making 36.

$$\frac{24\times 36}{16}=54 \text{ inches.}$$

The distance between the centres and velocities of two wheels being given, to find their proper diameters.

Rule.—Divide the greatest velocity by the least; the quotient is the ratio of diameter the wheels must bear to each other. Hence, divide the distance between the centres by the ratio plus 1; the quotient equal the radius of the smaller wheel; and subtract the radius thus obtained from the distance between the centres; the remainder equal the radius of the other.

Ex. The distance of two shafts from centre to centre is 50 inches, and the velocity of the one 25 revolutions per minute, the other is to make 80 in the same time; the proper diameters of the wheels at the pitch lines are required.

$80\div25=3{\cdot}2$, ratio of velocity, and $\frac{50}{3{\cdot}2+1}=11{\cdot}9$, the radius of the smaller wheel; then $50-11{\cdot}9=38{\cdot}1$, radius of larger; their diameters are $11{\cdot}9\times2=23{\cdot}8$, and $38{\cdot}1\times2=76{\cdot}2$ inches.

To obtain or diminish an accumulated velocity by means of wheels and pinions, or wheels, pinions, and pulleys, it is necessary that a proportional ratio of *velocity* should exist, and which is simply thus attained:—Multiply the given and required velocities together, and the square root of the product is the mean or proportionate velocity.

Ex. Let the given velocity of a wheel containing 54 teeth equal 16 revolutions per minute, and the given diameter of an intermediate pulley equal 25 inches, to obtain a velocity of 81 revolutions in a machine; required the number of teeth in the intermediate wheel, and diameter of the last pulley.

$\sqrt{81 \times 16} = 36$ mean velocity.

$\frac{54 \times 16}{36} = 24$ teeth, and $\frac{25 \times 36}{81} = 11 \cdot 1$ inches, diameter of pulley.

To determine the proportion of wheels for screw-cutting by a Lathe.

In a lathe properly adapted, screws to any degree of pitch, or number of threads in a given length, may be cut by means of a leading screw of any given pitch, accompanied with change wheels and pinions; course pitches being effected generally by means of one wheel and one pinion with a *carrier*, or *intermediate wheel*, which cause no variation or change of motion to take place: hence the following

Rule.—Divide the number of threads in a given length of the screw which is to be cut, by the number of threads in the same length of the leading screw attached to the lathe; and the quotient is the ratio that the wheel on the end of the screw must bear to that on the end of the lathe spindle.

Ex. Let it be required to cut a screw with 5 threads in an inch, the leading screw being of $\frac{1}{2}$ inch pitch, or containing two threads in an inch; what must be the ratio of wheels applied?

$5 \div 2 = 2 \cdot 5$, the ratio they must bear to each other.

Then suppose a pinion of 40 teeth be fixed upon for the spindle,—

$40 \times 2{\cdot}5 = 100$ teeth for the wheel on the end of the screw.

But screws of a greater degree of fineness than about 8 threads in an inch are more conveniently cut by an additional wheel and pinion, because of the proper degree of velocity being more effectively attained; and these, on account of revolving upon a stud, are commonly designated the *stud-wheels*, or *stud-wheel* and *pinion;* but the mode of calculation and ratio of screw are the same as in the preceding rule;—hence, all that is further necessary is to fix upon any 3 wheels at pleasure, as those for the spindle and stud-wheels,—then multiply the number of teeth in the spindle-wheel by the ratio of the screw, and by the number of teeth in that wheel or pinion which is in contact with the wheel on the end of the screw; divide the product by the stud-wheel in contact with the spindle-wheel, and the quotient is the number of teeth required in the wheel on the end of the leading screw.

Ex. Suppose a screw is required to be cut containing 25 threads in an inch, the leading screw as before having 2 threads in an inch, and that a wheel of 60 teeth is fixed upon for the end of the spindle, 20 for the pinion in contact with the screw wheel, and 100 for that in contact with the wheel on the end of the spindle;—required the number of teeth in the wheel for the end of the leading screw.

$$25 \div 2 = 12{\cdot}5, \text{ and } \frac{60 \times 12{\cdot}5 \times 20}{100} = 150 \text{ teeth.}$$

Or suppose the spindle and screw-wheels to be those fixed upon, also any one of the stud-wheels, to find the number of teeth in the other.

$$\frac{60 \times 12{\cdot}5}{150 \times 100} = 20 \text{ teeth, or } \frac{60 \times 12{\cdot}5 \times 20}{150} = 100 \text{ teeth.}$$

Table of Change Wheels for Screw Cutting, the leading screw being of ½-inch pitch, or containing 2 threads in an inch.

Number of threads in inch of screw.	Numb. of teeth in		Number of threads in inch of screw.	Number of teeth in				Number of threads in inch of screw.	Number of teeth in			
	Lathe spindle-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.
1	80	40	8¼	40	55	20	60	19	50	95	20	100
1¼	80	50	8½	90	85	20	90	19½	80	120	20	130
1½	80	60	8¾	60	70	20	75	20	60	100	20	120
1¾	80	70	9½	90	90	20	95	20¼	40	90	20	90
2	80	90	9¾	40	60	20	65	21	80	120	20	140
2¼	80	90	10	60	75	20	80	22	60	110	20	120
2½	80	100	10½	50	70	20	75	22½	80	120	20	150
2¾	80	110	11	60	55	20	120	22¾	80	130	20	140
3	80	120	12	90	90	20	120	23¾	40	95	20	100
3¼	80	130	12¾	60	85	20	90	24	65	120	20	130
3½	80	140	13	90	90	20	130	25	60	100	20	150
3¾	80	150	13½	60	90	20	90	25½	30	85	20	90
4	40	80	13¾	80	100	20	110	26	70	130	20	140
4¼	40	85	14	90	90	20	140	27	40	90	20	120
4½	40	90	14¼	60	90	20	95	27½	40	100	20	110
4¾	40	95	15	90	90	20	150	28	75	140	20	150
5	40	100	16	60	80	20	120	28½	30	90	20	95
5½	40	110	16¼	80	100	20	130	30	70	140	20	150
6	40	120	16½	80	110	20	120	32	30	80	20	120
6½	40	130	17	45	85	20	90	33	40	110	20	120
7	40	140	17½	80	100	20	140	34	30	85	20	120
7½	40	150	18	40	60	20	120	35	60	140	20	150
8	30	120	18¾	80	100	20	150	36	30	90	20	120

Table by which to determine the Number of Teeth, o Pitch of Small Wheels, by what is commonly calle the Manchester principle.

Diametral pitch.	Circular pitch.	Diametral pitch.	Circular pitch.
3	1·047	9	·349
4	·785	10	·314
5	·628	12	·262
6	·524	14	·224
7	·449	16	·196
8	·393	20	·157

Ex. 1. Required the number of teeth that a wh of 16 inches diameter will contain of a 10 pitch.

16 × 10=160 teeth, and the circular pitch=·314 inch.

Ex. 2. What must be the diameter of a wheel a 9 pitch of 126 teeth?

$\frac{126}{9}$=14 inches diameter, circular pitch ·349 inch.

Note.—The pitch is reckoned on the diameter of the wh instead of the circumference, and designated wheels of 8 pit 12 pitch, &c.

Strength of the Teeth of Cast-Iron Wheels at a giv velocity.

Pitch of teeth in inches.	Thickness of teeth in inches.	Breadth of teeth in inches.	Strength of teeth in horse-power,			
			3 ft. per second.	4 ft. per second.	6 ft. per second.	8 ft. seco
3·99	1·9	7·6	20·57	27·43	41·14	54·8
3·78	1·8	7·2	17·49	23·32	34·98	46·6
3·57	1·7	6·8	14·73	19·65	29·46	39·2
3·36	1·6	6·4	12·28	16·38	24·56	32·7
3·15	1·5	6	10·12	13·50	20·24	26·9
2·94	1·4	5·6	8·22	10·97	16·44	21·9
2·73	1·3	5·2	6·58	8·78	13·16	17·5
2·52	1·2	4·8	5·18	6·91	10·36	13·8
2·31	1·1	4·4	3·99	5·32	7·98	10·6
2·1	1·0	4	3·00	4·00	6·00	8·0
1·89	·9	3·6	2·18	2·91	4·36	5·8
1·68	·8	3·2	1·53	2·04	3·08	3·
1·47	·7	2·8	1·027	1·37	2·04	2
1·26	·6	2·4	·64	·86	1·38	
1·05	·5	2	·375	·50	·75	

teeth at a given pitch.

Number of teeth.	Pitch of the teeth in inches.												
	1 inch	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2 inch	2⅛	2¼	2½	2¾	3 inch
	Diameter at the pitch circle in feet and inches.													
10	0 3¼	0 3⅝	0 4	0 4½	0 4⅞	0 5¼	0 5⅝	0 6	0 6½	0 6⅞	0 7¼	0 8	0 8⅞	0 9⅝
11	0 3½	0 4	0 4⅜	0 5	0 5⅜	0 5¾	0 6¼	0 6⅝	0 7	0 7½	0 7⅞	0 8¾	0 9¾	0 10⅝
12	0 3⅞	0 4⅜	0 4⅞	0 5⅜	0 5⅞	0 6⅜	0 6¾	0 7⅛	0 7⅝	0 8⅛	0 8⅝	0 9⅝	0 10⅝	0 11½
13	0 4⅛	0 4¾	0 5¼	0 5¾	0 6¼	0 6⅞	0 7⅜	0 7⅞	0 8⅜	0 8⅞	0 9⅜	0 10⅜	0 11½	1 0½
14	0 4½	0 5	0 5⅝	0 6¼	0 6¾	0 7⅜	0 7⅞	0 8½	0 9	0 9½	0 10	0 11¼	1 0⅜	1 1½
15	0 4⅞	0 5⅜	0 6	0 6⅝	0 7¼	0 7⅞	0 8½	0 9	0 9⅝	0 10¼	0 10¾	1 0	1 1¼	1 2⅜
16	0 5⅛	0 5¾	0 6⅜	0 7	0 7⅝	0 8⅜	0 9	0 9⅝	0 10¼	0 10⅞	0 11½	1 0¾	1 2	1 3⅜
17	0 5½	0 6⅛	0 6¾	0 7½	0 8¼	0 8⅞	0 9⅝	0 10¼	0 10⅞	0 11½	1 0¼	1 1½	1 2⅞	1 4¼
18	0 5¾	0 6½	0 7⅛	0 8	0 8⅝	0 9⅜	0 10	0 10¾	0 11½	1 0¼	1 0⅞	1 2⅜	1 3¾	1 5¼
19	0 6	0 6⅞	0 7½	0 8⅜	0 9⅛	0 9⅞	0 10⅝	0 11⅜	1 0⅛	1 0⅞	1 1⅝	1 3⅛	1 4⅝	1 6¼
20	0 6⅜	0 7⅛	0 8	0 8⅞	0 9⅝	0 10⅜	0 11¼	1 0	1 0¾	1 1½	1 2⅜	1 4	1 5½	1 7⅛
21	0 6¾	0 7½	0 8⅜	0 9¼	0 10	0 11	0 11¾	1 0½	1 1⅜	1 2¼	1 3	1 4¾	1 6⅜	1 8⅛
22	0 7	0 7⅞	0 8¾	0 9⅝	0 10⅝	0 11½	1 0⅜	1 1⅛	1 2	1 2⅞	1 3¾	1 5½	1 7¼	1 9
23	0 7⅜	0 8¼	0 9⅛	0 10	0 11	1 0	1 0⅞	1 1¾	1 2⅝	1 3½	1 4½	1 6⅜	1 8	1 10
24	0 7⅝	0 8⅝	0 9½	0 10½	0 11½	1 0½	1 1⅜	1 2⅜	1 3⅜	1 4¼	1 5¼	1 7⅛	1 9	1 10⅞
25	0 8	0 9	0 10	0 11	1 0	1 1	1 2	1 2⅞	1 3⅞	1 4⅞	1 6	1 8	1 9⅞	1 11⅞
26	0 8¼	0 9¼	0 10⅜	0 11½	1 0½	1 1½	1 2½	1 3½	1 4½	1 5½	1 6⅝	1 8¾	1 10¾	2 0⅞
27	0 8⅝	0 9⅝	0 10¾	0 11⅞	1 1	1 2	1 3	1 4⅛	1 5¼	1 6¼	1 7⅜	1 9½	1 11⅝	2 1¾
28	0 9	0 10	0 11¼	1 0¼	1 1¼	1 2½	1 3⅝	1 4⅝	1 5¾	1 6⅞	1 8	1 10¼	2 0½	2 2¾
29	0 9¼	0 10⅜	0 11⅝	1 0¾	1 1⅞	1 3	1 4⅛	1 5⅜	1 6½	1 7⅝	1 8¾	1 11⅛	2 1⅜	2 3¾

Table of the Diameters of Wheels—continued.

Number of teeth.	Pitch of the teeth in inches.																											
	1 inch		1⅛		1¼		1⅜		1½		1⅝		1¾		1⅞		2 inch		2⅛		2¼		2½		2¾		3 inch	
	Diameter at the pitch circle in feet and inches.																											
30	0	9½	0	10¾	1	0	1	1⅛	1	2⅜	1	3½	1	4½	1	6	1	7⅛	1	8¼	1	9½	2	0	2	2¼	2	4⅝
31	0	9⅞	0	11⅛	1	0⅜	1	1⅝	1	2⅞	1	4	1	5⅜	1	6½	1	7¾	1	9	1	10¼	2	0¾	2	3⅛	2	5⅝
32	0	10¼	0	11½	1	0¾	1	2	1	3⅜	1	4⅝	1	5⅞	1	7⅛	1	8⅜	1	9⅝	1	11	2	1½	2	4	2	6½
33	0	10½	0	11⅞	1	1⅛	1	2⅛	1	3¾	1	5⅛	1	6½	1	7¾	1	9	1	10⅜	1	11⅝	2	2¼	2	4⅞	2	7½
34	0	10⅞	1	0⅛	1	1⅝	1	3	1	4¼	1	5⅝	1	7	1	8⅜	1	9⅝	1	11	2	0⅜	2	3	2	5¾	2	8½
35	0	11⅛	1	0⅝	1	2	1	3⅜	1	4¾	1	6⅛	1	7½	1	9	1	10⅛	1	11¾	2	1	2	3⅞	2	6⅝	2	9½
36	0	11½	1	1	1	2⅜	1	3¾	1	5¼	1	6⅝	1	8	1	9½	1	10⅞	2	0⅜	2	2	2	4⅝	2	7½	2	10⅜
37	0	11¾	1	1¼	1	2¾	1	4¼	1	5⅝	1	7¼	1	8⅝	1	10	1	11½	2	1	2	2½	2	5½	2	8⅜	2	11⅜
38	1	0⅛	1	1⅝	1	3¼	1	4⅝	1	6¼	1	7⅝	1	9¼	1	10¾	2	0¼	2	1¾	2	3¼	2	6¼	2	9¼	3	0¼
39	1	0⅜	1	2	1	3½	1	5	1	6⅝	1	8¼	1	9¾	1	11⅜	2	0⅞	2	2⅜	2	4	2	7	2	10⅛	3	1¼
40	1	0¾	1	2⅜	1	4	1	5½	1	7⅜	1	8¾	1	10⅜	1	11⅞	2	1½	2	3	2	4⅝	2	7⅞	2	10¾	3	2¼
41	1	1	1	2¾	1	4⅜	1	6	1	7⅝	1	9¼	1	10⅞	2	0½	2	2⅛	2	3¾	2	5⅜	2	8⅝	2	11⅞	3	3⅛
42	1	1⅜	1	3	1	4¾	1	6⅜	1	8	1	9¾	1	11½	2	1	2	2¾	2	4½	2	6	2	9⅜	3	0¾	3	4⅛
43	1	1⅝	1	3½	1	5⅛	1	6⅞	1	8⅝	1	10¼	2	0	2	1⅝	2	3⅜	2	5	2	6¾	2	10¼	3	1⅝	3	5
44	1	2	1	3¾	1	5⅝	1	7¼	1	9	1	10¾	2	0½	2	2¼	2	4	2	5¾	2	7½	2	11	3	2½	3	6
45	1	2⅜	1	4⅛	1	6	1	7¾	1	9½	1	11⅜	2	1	2	2⅞	2	4⅝	2	6½	2	8¼	2	11¾	3	3⅜	3	7
46	1	2⅝	1	4½	1	6⅜	1	8⅛	1	10	1	11⅞	2	1⅝	2	3½	2	5¼	2	7⅛	2	9	3	0⅝	3	4¼	3	7⅞
47	1	2⅞	1	4⅞	1	6¾	1	8⅝	1	10½	2	0⅜	2	1⅞	2	4	2	6	2	7⅞	2	9⅝	3	1½	3	5⅛	3	8⅞
48	1	3¼	1	5¼	1	7⅛	1	9	1	11	2	0⅞	2	2¾	2	4⅝	2	6½	2	8½	2	10⅜	3	2¼	3	6	3	9⅞
49	1	3½	1	5⅝	1	7½	1	9½	1	11½	2	1⅜	2	3⅜	2	5¼	2	7¼	2	9⅛	2	11	3	3	3	6⅞	3	10⅞
50	1	3⅞	1	6	1	8	1	9⅞	2	0	2	1⅞	2	3⅞	2	5⅞	2	7⅞	2	9¾	2	11¾	3	3¾	3	7¾	3	11¾

51	1	4¼	1	6¼	1	8⅜	1	10⅜	2	0⅜	2	2⅜	2	4½	2	6½	2	8½	2	10½	3	0½	3	4½	3	8⅝	4	0¾
52	1	4½	1	6⅝	1	8¾	1	10¾	2	0⅞	2	2⅞	2	4⅞	2	7⅛	2	9⅛	2	11⅛	3	1¼	3	5⅜	3	9½	4	1⅝
53	1	4⅞	1	6⅞	1	9⅛	1	11¼	2	1¼	2	3⅜	2	5⅝	2	7⅝	2	9¾	2	11⅞	3	2	3	6¼	3	10½	4	2⅝
54	1	5⅛	1	7⅜	1	9½	1	11⅝	2	1¾	2	3⅞	2	6	2	8¼	2	10⅜	3	0½	3	2⅝	3	7	3	11	4	3½
55	1	5½	1	7¾	1	9⅞	2	0	2	2¼	2	4½	2	6⅝	2	8⅞	2	11	3	1¼	3	3½	3	7¾	4	0⅛	4	4½
56	1	5⅞	1	8⅛	1	10¼	2	0½	2	2¾	2	4⅞	2	7⅛	2	9⅜	2	11⅝	3	1⅞	3	4⅛	3	8½	4	1	4	5½
57	1	6⅛	1	8½	1	10⅝	2	0⅞	2	3¼	2	5¼	2	7¾	2	10	3	0¼	3	2½	3	4⅞	3	9⅜	4	1⅞	4	6⅜
58	1	6½	1	8¾	1	11	2	1⅜	2	3⅝	2	6	2	8¼	2	10⅝	3	0⅞	3	3¼	3	5½	3	10⅛	4	2¾	4	7⅜
59	1	6¾	1	9⅛	1	11½	2	1⅞	2	4⅛	2	6½	2	8⅞	2	11¼	3	1½	3	4	3	6¼	3	11⅛	4	3⅝	4	8⅜
60	1	7⅛	1	9½	1	11⅞	2	2¼	2	4⅝	2	7	2	9⅜	2	11¾	3	2¼	3	4⅝	3	7	3	11¾	4	4½	4	9¼
61	1	7½	1	9⅞	2	0¼	2	2¾	2	5¼	2	7½	2	10	3	0⅜	3	2⅞	3	5¼	3	7¾	4	0½	4	5⅜	4	10¼
62	1	7¾	1	10¼	2	0⅝	2	3⅛	2	5⅝	2	8	2	10½	3	1	3	3½	3	6	3	8½	4	1⅜	4	6¼	4	11¼
63	1	8	1	10½	2	1	2	3½	2	6	2	8⅝	2	11	3	1⅝	3	4⅛	3	6⅝	3	9⅛	4	2⅛	4	7⅛	5	0⅛
64	1	8⅜	1	10⅞	2	1½	2	4	2	6½	2	9⅛	2	11⅝	3	2¼	3	4¾	3	7¼	3	9⅞	4	3	4	8	5	1⅛
65	1	8⅝	1	11¼	2	1⅞	2	4½	2	7	2	9⅝	3	0¼	3	2⅞	3	5⅜	3	8	3	10½	4	3¾	4	8⅞	5	2
66	1	9	1	11⅝	2	2¼	2	4⅞	2	7½	2	10⅛	3	0⅞	3	3⅜	3	6	3	8⅝	3	11¼	4	4½	4	9¾	5	3
67	1	9⅜	2	0	2	2⅝	2	5¼	2	8	2	10⅝	3	1⅜	3	4	3	6½	3	9⅜	4	0	4	5⅜	4	10⅝	5	4
68	1	9⅝	2	0⅜	2	3	2	5¾	2	8½	2	11⅛	3	1¾	3	4⅝	3	7¼	3	10	4	0¾	4	6⅛	4	11½	5	5
69	1	9⅞	2	0¾	2	3½	2	6¼	2	8⅞	2	11¾	3	2⅜	3	5⅛	3	7⅞	3	10⅝	4	1½	4	7	5	0⅜	5	6
70	1	10¼	2	1	2	3⅞	2	6⅝	2	9⅜	3	0¼	3	3	3	5¾	3	8½	3	11⅜	4	2⅛	4	7¾	5	1¼	5	6⅞
71	1	10⅝	2	1½	2	4¼	2	7	2	9⅞	3	0⅞	3	3½	3	6⅜	3	9¼	4	0	4	2⅞	4	8½	5	2⅛	5	7¾
72	1	10⅞	2	1¾	2	4⅝	2	7½	2	10⅜	3	1⅜	3	4⅛	3	6¾	3	9⅞	4	0¾	4	3½	4	9¼	5	3	5	8¾
73	1	11¼	2	2⅛	2	5	2	8	2	10⅞	3	1¾	3	4⅝	3	7½	3	10½	4	1⅜	4	4¼	4	10	5	3⅞	5	9¾
74	1	11½	2	2½	2	5½	2	8⅜	2	11⅜	3	2¼	3	5¼	3	7⅞	3	11⅛	4	2	4	5	4	10⅞	5	4¾	5	10⅝
75	1	11⅞	2	2⅞	2	5⅞	2	8⅞	2	11⅞	3	2¾	3	5¾	3	8¾	3	11¾	4	2¾	4	5¾	4	11¾	5	5⅝	5	11⅝
76	2	0⅛	2	3¼	2	6¼	2	9¼	3	0¼	3	3¼	3	6⅜	3	9⅜	4	0⅜	4	3½	4	6½	5	0½	5	6½	6	0½
77	2	0½	2	3½	2	6⅝	2	9¾	3	0¾	3	3⅞	3	6⅞	3	9⅞	4	1	4	4	4	7⅛	5	1¼	5	7⅜	6	1½
78	2	0⅞	2	3⅞	2	7	2	10⅛	3	1½	3	4⅜	3	7½	3	10½	4	1⅝	4	4¾	4	7⅞	5	2	5	8¼	6	2½
79	2	1⅛	2	4⅛	2	7⅜	2	10½	3	1¾	3	4⅞	3	8	3	11⅛	4	2¼	4	5½	4	8½	5	2⅞	5	9⅛	6	3½

Table of the Diameters of Wheels—continued.

Number of teeth.	Pitch of the teeth in inches.																											
	1 inch		1⅛		1¼		1⅜		1½		1⅝		1¾		1⅞		2 inch		2⅛		2¼		2½		2¾		3 inch	
	Diameter at the pitch circle in feet and inches.																											
30	0	9½	0	10¾	1	0	1	1⅛	1	2⅜	1	3½	1	4½	1	6	1	7⅛	1	8¼	1	9½	2	0	2	2¼	2	4⅝
31	0	9⅞	0	11⅛	1	0⅜	1	1⅝	1	2⅞	1	4	1	5⅜	1	6½	1	7¾	1	9	1	10¼	2	0¾	2	3⅛	2	5⅝
32	0	10¼	0	11½	1	0¾	1	2	1	3⅜	1	4⅝	1	5⅞	1	7⅛	1	8⅜	1	9⅝	1	11	2	1½	2	4	2	6½
33	0	10½	0	11⅞	1	1⅛	1	2½	1	3¾	1	5⅛	1	6½	1	7¾	1	9	1	10⅜	1	11⅝	2	2¼	2	4⅞	2	7½
34	0	10⅞	1	0⅛	1	1⅝	1	3	1	4¼	1	5⅝	1	7	1	8⅜	1	9⅝	1	11	2	0⅜	2	3	2	5¾	2	8½
35	0	11⅛	1	0⅝	1	2	1	3⅜	1	4¾	1	6⅛	1	7½	1	9	1	10⅛	1	11¾	2	1	2	3⅞	2	6⅝	2	9½
36	0	11½	1	1	1	2⅜	1	3¾	1	5¼	1	6⅝	1	8	1	9½	1	10⅞	2	0⅜	2	2	2	4⅝	2	7½	2	10⅜
37	0	11¾	1	1¼	1	2¾	1	4¼	1	5⅝	1	7¼	1	8⅝	1	10	1	11½	2	1	2	2½	2	5½	2	8⅜	2	11⅜
38	1	0⅛	1	1⅝	1	3¼	1	4⅝	1	6¼	1	7⅝	1	9¼	1	10¾	2	0¼	2	1¾	2	3¼	2	6¼	2	9¼	3	0¼
39	1	0⅜	1	2	1	3½	1	5	1	6⅝	1	8¼	1	9¾	1	11⅜	2	0⅞	2	2⅜	2	4	2	7	2	10⅛	3	1¼
40	1	0¾	1	2⅜	1	4	1	5½	1	7⅜	1	8¾	1	10⅜	1	11⅞	2	1½	2	3	2	4⅝	2	7⅞	2	10¾	3	2¼
41	1	1	1	2¾	1	4⅜	1	6	1	7⅝	1	9¼	1	10⅞	2	0½	2	2⅛	2	3¾	2	5⅜	2	8⅝	2	11⅞	3	3⅛
42	1	1⅜	1	3	1	4¾	1	6⅜	1	8	1	9¾	1	11½	2	1	2	2¾	2	·4½	2	6	2	9⅜	3	0¾	3	4⅛
43	1	1⅝	1	3½	1	5⅛	1	6⅞	1	8⅝	1	10¼	2	0	2	1⅝	2	3⅜	2	5	2	6¾	2	10¼	3	1⅝	3	5
44	1	2	1	3¾	1	5⅝	1	7¼	1	9	1	10¾	2	0½	2	2¼	2	4	2	5¾	2	7½	2	11	3	2½	3	6
45	1	2⅜	1	4⅛	1	6	1	7¾	1	9½	1	11⅜	2	1	2	2⅞	2	4⅝	2	6½	2	8¼	2	11¾	3	3⅜	3	7
46	1	2⅝	1	4½	1	6⅜	1	8⅛	1	10	1	11⅞	2	1⅝	2	3½	2	5¼	2	7⅛	2	9	3	0⅝	3	4¼	3	7⅞
47	1	2⅞	1	4⅞	1	6¾	1	8⅝	1	10½	2	0⅜	2	1⅞	2	4	2	6	2	7⅞	2	9⅝	3	1½	3	5⅛	3	8⅞
48	1	3¼	1	5¼	1	7⅛	1	9	1	11	2	0⅞	2	2¾	2	4⅝	2	6½	2	8½	2	10⅜	3	2¼	3	6	3	9⅞
49	1	3½	1	5⅝	1	7½	1	9½	1	11½	2	1⅜	2	3⅜	2	5¼	2	7¼	2	9⅛	2	11	3	3	3	6⅞	3	10⅞
50	1	3⅞	1	6	1	8	1	9⅞	2	0	2	1⅞	2	3⅞	2	5⅞	2	7⅞	2	9¾	2	11¾	3	3¾	3	7¾	3	11¾

FRICTION.

Friction is an effect produced by bodies rubbing one upon another, which acts as a retarding influence in the motion of all mechanical contrivances, but might not unfrequently be considerably diminished by a due regard to its laws, and a proper attention to the selection of those materials on which a uniform smooth surface may be attained, and which, according to experiments, are least liable to tear or become hot, and cause a roughness to arise when in working contact.

Several doubts existed a few years since respecting the laws of friction; but those doubts were entirely removed through the experiments of Mr. G. Rennie, on his own account, and those of M. Morin, acting for and under the sanction of the French Government, from or by which the following laws have been fully established.

1. That when no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) is directly proportional to the force with which they are pressed perpendicularly together; so that for any two given surfaces of contact, there is a constant ratio of the friction to the perpendicular pressure; that is, a double pressure will produce a double amount of friction, a triple pressure a triple amount, &c., of any other proportionate increase of the load.

2. That when no unguent is interposed, the amount of the friction is in every case wholly independent of the extent of the surfaces in contact; so that the force

with which two surfaces are pressed together being the same, their friction is the same, whatever may be the extent of their surfaces of contact.

3. That the friction of motion is wholly independent of the velocity of the motion; that is, supposing two shafts or axles of equal bearings and of equal weights or pressures, but the one making 100 revolutions while the other makes but 50, the amount of friction in each is alike.

4. That when unguents are interposed, the amount of friction depends more upon the nature of the unguent than upon that of the surfaces of contact; and hence, that the nature of the unguent to be applied must be governed by the pressure or insistent weight. Mr. Rennie found, that with the unguents tallow and anti-attrition, on axles under a pressure of from 1 to 5 cwt., the friction did not exceed $\frac{1}{39}$th of the whole pressure; but when softer unguents were applied, as oil, hog's-lard, &c., the ratio of the friction to the pressure considerably increased; from which it is naturally inferred that the consistence of an unguent ought just to prevent the bodies coming into contact with each other.

5. That the friction of metals, without a stratum of unguent interposed, varies as their hardness, the hard metals producing less friction than the soft ones.

6. That without unguents, and within the limits of 32½℔s. pressure per square inch, the friction of hard metals upon hard metals may very generally be estimated at about $\frac{1}{6}$th of the whole pressure.

7. That within the limits of their abrasion, the friction of metals is nearly alike; but from 1·66 cwt. per square inch to 6 cwt. per square inch, the resistance increases in a very considerable ratio, being the greatest with steel on cast iron, and the least with brass on wrought iron.

PRACTICAL PROPERTIES OF WATER AND AIR;

OR OF LIQUIDS AND FLUIDS IN GENERAL.

WATER is the most abundant liquid we possess, and is the most abundant fluid,—their properties con- ıuting largely to the subserviency of man, not only he support of his existence and the comforts of domestic enjoyments, but because of inherent rgies which render them exceedingly advantageous, h as an efficient and disposable source of motive ver.

By analysis it is ascertained that water is composed he gases *oxygen* and *hydrogen* in a state of chemi- union; its distinguishing properties, like that of er liquids, being incompressibility,* gravity, capa- ty of flowing, and constant tendency to press out- ds in every direction; also that of being easily nged by the absorption of caloric to an aëriform e of any required density or degree of elastic force: ıce the principle of the *hydraulic press*, the *water- el*, the *steam engine*, &c.

Atmospheric air, like water, is also a gaseous com- ınd: of 100 parts of air, reckoning by weight, 55 parts are nitrogen, 23·32 oxygen, and 1·13 car- ıic acid and watery vapour; and in such proportions

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Exact experiments have determined that water is not en- ly incompressible, but the degree of compressibility is so ll, being only about 46½ millionth parts per atmosphere, the terms *incompressible* and non-elastic fluid are not at *practice inappropriate.*

it is most conducive to animal existence. It also in this state possesses many important mechanical properties, a few of which are the following: viz., gravity, fluidity, compressibility, force or pressure, and elasticity; also expansibility by rarefaction or heat; and it is because of the oxygen it contains that combustion is supported. By change of temperature in the atmosphere, currents and winds are created; hence the means by which vessels are enabled to make distant voyages; also the cause which produces circular motion through the medium of the sails of a wind-mill: and it may likewise be observed, that without the pressure of the atmosphere the common pump would be without effect. Such preliminaries being properly considered, tend much to pave the way to an efficient knowledge of those elements, *water* and *air*, either as regards the production of, or retarding mechanical effects in their application as motive power.

1. *Effects produced by water in its natural state.*

Because of liquids possessing the properties of gravity and capability of flowing freely in every direction, sides of vessels, flood-gates, sluices, &c., sustain a pressure equal to the product of the area multiplied by half the depth of the fluid, and by its gravity, in equal terms of unity.

But when a sluice or opening through which a liquid may issue is under any given continued head, the pressure is equal the product of the area multiplied into the height from the centre of the opening to the surface of the fluid.

Ex. 1. Required the pressure of water on the sides of a rectangular cistern 18 feet in length, 13 in width, and 9 in depth.

The terms of measurement or unity are in feet; 1 cubic foot of water $= 62{\cdot}5$ lbs.; hence $\overline{18 \times 9 \times 2} + \overline{13 \times 9 \times 2} = 558 \times 4{\cdot}5 \times 62{\cdot}5 = 156937{\cdot}5$ lbs.

Weight of water on bottom $= 18 \times 13 \times 9 \times 62{\cdot}5 = 131625$ lbs.

Ex. 2. Required the pressure on a sluice 3 feet square, and its centre 30 feet from the surface of the water.

$3 \times 3 \times 30 \times 62{\cdot}5 = 16875$ lbs. pressure.

The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height; hence, as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

Ex. Let a cubical vessel whose sides are each 4 square feet have a tube inserted 1 inch in diameter and 6 feet in height, and let both vessel and tube be filled with water; required the whole weight of the water therein contained, and also the whole pressure exerted in tending to burst the vessel.

Cubic contents of the vessel $= 8$ feet, and each foot $= 62{\cdot}5$ lbs. (see page 55).

Then, $62{\cdot}5 \times 8 = 500$. Area of pipe's section $= {\cdot}7854$ inches and height 72 in., also a cubic inch of water $= {\cdot}03617$ lbs.; hence ${\cdot}7854 \times 72 \times {\cdot}03617 = 2$ lbs. $+ 500 = 502$ lbs. total weight of the water.

Again, the whole height of the column $= 96$ inches; then ${\cdot}7854 \times 96 \times {\cdot}03617 = 2{\cdot}33$ lbs., pressure of column on an equal area. 144 square inches $= 1$ square foot, and $\frac{144 \times 4 \times 6 \text{ sides}}{{\cdot}7854} = 4400{\cdot}4$ times the area of the pipe's diameter in the whole surface; therefore $4400{\cdot}4 \times 2{\cdot}33$ *$= 10258$ lbs., or total amount of pressure exerted.*

Upon the preceding principles of water rests the utility of the hydraulic press. Thus, into a uniform cylinder of suitable strength is fitted a piston or ram moveable in a parallel direction, around which are properly fitted leather collars, to prevent any possibility of the water's escape; the water being injected by means of a force-pump, and, by its non-compressible property, repelling the ram with a force equal to the number of times the end of the ram exceeds the area of the pump.

Ex. Required the repulsive force of a 6-inch ram, when a power of 50℔s. is applied to the end of the lever, which is as 12 to 1 in effect, and the diameter of the pump or plunger ⅞ths of an inch.

$$\frac{\text{Area of ram} = 28\cdot2744}{\text{Area of pump} = \cdot6013} = 47\,;$$

and 50 × 12 × 47 = 28200 ℔s., or 12 tons nearly.

When a body is partly or wholly immersed in water or other fluid, the vertical pressure of the fluid tends to raise the body with a force equal to the weight of the fluid displaced; hence the weight of any displaced quantity of a fluid by a buoyant body equals the weight of that body.

Ex. 1. Suppose a vessel with all its masts, stores, and general equipments, is found to displace 35,000 cubic feet of sea water, what is the whole weight of the vessel?

Sea water average 64 ℔s. per cubic foot.

$$\frac{35000 \times 64}{2240} = 1000 \text{ tons.}$$

Ex. 2. What must be the thickness of sheet iron *whereby to form* a rectangular vessel 5 feet in length, *2 in width*, and 1¼ in depth, that will just sink 3 inches in common water; laps, seams, and rivets not being taken into account?

5 ft. or 60 in. × 15=900 × 2=1800 in., or sum of the sides.
„ 60 „ × 15= 1440 „ bottom.
2 „ 24 „ × 15=360 × 2= 720 „ ends.
Total 3960
And 3960 × ·281 (see page 30)=1112·7, the divisor.
Then 60 in. × 15 × 3 × ·03617 = 156·254 lbs. of water to displace.
Hence $\frac{156{\cdot}254}{1112{\cdot}7}$ = ·14 in., the thickness of iron required.

The resistance by which a moving body is opposed in passing through water is as the square of the body's velocity; hence, if a body be propelled at a certain velocity by a known power, to double that velocity will require four times the power; to triple it, nine times the power, &c.

Water in flowing through an orifice or aperture under any given head, is governed by the same law of gravity as that of a solid body in vacuo descending through the same space, or falling from an equal height; but as friction is created by the motion of two hard bodies in contact, so is friction also created by the action of the water in passing through the orifice or aperture: hence an aperture twice the width of another will discharge more than a double quantity, because of the area advancing in a much greater ratio to that of the resistance. Thus, suppose an opening of 4 square feet be required: in a circular form its diameter would be about 2 feet 3 inches, and its circumference, or cause of friction, 7 feet; in a square form, 2 feet by 2 feet, and the amount of its sides 8 feet; but in a rectangular form, 4 feet in length *and 1 in breadth,* the cause of resistance is increased to 10 feet; thus showing that the circular form is that which ought to be adopted in preference to any other for the conduction of water where practicability will admit.

When water issues out of a circular orifice in a thin plate at the bottom or side of a reservoir, the issuing stream tends to converge to a point at the distance of about half its diameter outside the orifice, and this contraction of the stream reduces the area of its section from 1 to ·619, or nearly ⅝ths. If a short parallel tube be attached, the vein of the stream is less contracted, and the area will equal ·762. But if the tube attached be the frustum of a cone whose greater end is the aperture, the length equal half the diameter of the aperture, and the area of the small end to the area of the larger as 1 to 1·6, there will be no contraction of the vein: hence the propriety of making the pipe in this form from a reservoir or other head of water, through which the greatest quantity, according to its area, is required to pass.

To find the velocity of water issuing through a circular orifice at any given depth from the surface.

Rule.—Multiply the square root of the height or depth to the centre of the orifice by 8·1, and the product is the velocity of the issuing fluid in feet per second.

Ex. Required the velocity of water issuing through an orifice under a head of 11 feet from the surface.

$\sqrt{11}=3{\cdot}3166\times 8{\cdot}1=26{\cdot}864$ feet, velocity per second.

In the discharge of water by a rectangular aperture in the side of a reservoir, and extending to the surface, the velocity varies nearly as the square root of the height, and the quantity discharged per second equal

⅔rds of the velocity due to the mean height, allowing for the contraction of the fluid according to the form of the opening, which renders the co-efficient in this case equal to 5·1; whence the following general rules.

1. *When the aperture extends to the surface of the fluid.* Multiply the area of the opening in feet by the square root of its depth, also in feet, and that product by 5·1; then will ⅔rds of the last product equal the quantity discharged in cubic feet per second.

2. *When the aperture is under a given head.* Multiply the area of the aperture in feet by the square root of the depth also in feet, and by 5·1; the product is the quantity discharged in cubic feet per second.

Ex. 1. Required the quantity of water in cubic feet per second discharged through an opening in the side of a dam or weir, the width or length of the opening being 6½ feet, and depth 9 inches, or ·75 of a foot,

Square root of ·75=·866.

Then $\frac{6{\cdot}5 \times {\cdot}75 \times {\cdot}866 \times 5{\cdot}1 \times 2}{3} = 14{\cdot}3839$ cubic feet.

Ex. 2. What would be the quantity discharged through the above opening if under a head of water 4 feet in height?

Square root of 4=2, and 2×5·1=10·2 feet, velocity of the water per second.

And 6·5 × ·75 × 2 × 5·1=49·725 cubic feet discharged in the same time.

PRACTICAL RULES BY WHICH TO DETERMINE THE NECESSARY HEAD, AND QUANTITY OF WATER DISCHARGED THROUGH CIRCULAR PIPES IN A GIVEN TIME.

Rule 1.—To the product of the pipe's length in feet, multiplied by the square of the quantity required in cubic feet per second, add the product of 50 times the pipe's diameter in feet, multiplied into the square of the required quantity per second; divide the sum by the product of 1542·133 into the fifth power of the diameter, and the quotient equal the *head* in feet to produce the velocity required.

Rule 2.—Multiply 1542·133 times the fifth power of the pipe's diameter in feet by the head of water in feet, and divide the product by the sum of the pipe's length and 50 times its diameter; the square root of the quotient equal the *quantity* discharged in cubic feet per second.

Ex. 1. Required the head of water necessary to produce a velocity of 2·988 feet, or 9·387 cubic feet per second, by a pipe of 2 feet in diameter and 180 feet in length.

$$\frac{\overline{9{\cdot}387^2 \times 180} + \overline{50 \times 2 \times 9{\cdot}387^2}}{1542{\cdot}133 \times 2^5} = \frac{15860{\cdot}8}{49348} = {\cdot}5 \text{ of a foot head.}$$

Ex. 2. What quantity of water per second will be discharged through a pipe of 2 feet diameter and 180 feet in length, when pressed by a head of water ·5 of a foot in height.

$$\frac{1542{\cdot}133 \times 2^5 \times {\cdot}5}{180 + \overline{50 \times 2}} = \sqrt{88{\cdot}1219} = 9{\cdot}387 \text{ feet per second.}$$

And the area of the end of the pipe in feet, multiplied into the velocity, equal the quantity in cubic feet.

Note.—The above rules apply strictly only to straight pipes; bends in a pipe diminish the velocity of a fluid equal to ·0038 mos the sum of the sines of the several angles of inflection; ence, a bend in a pipe should not be sudden, and on no ac- ount should an angle be admitted.

able of the Diameters of Pipes through which a required quantity of water may be discharged in a given time.

ubic feet er minute.	Diameter in inches.	Cubic feet per minute.	Diameter in inches.	Cubic feet per minute.	Diameter in inches.
1	1	25	4¾	160	12⅛
2	1⅜	30	5¼	170	12½
3	1⅝	35	5⅝	180	12¾
4	1⅞	40	6	190	13¼
5	2⅛	45	6½	200	13⅝
6	2⅜	50	6¾	225	14⅜
7	2½	55	7⅛	250	15⅛
8	2¾	60	7½	275	16
9	2⅞	65	7¾	300	16⅝
10	3	70	8	350	18
11	3⅛	80	8⅝	400	19¼
12	3¼	90	9⅛	441	20⅛
13	3½	100	9⅝	520	22
14	3⅝	110	10	625	24
15	3¾	120	10½	729	26
16	3⅞	130	11	841	28
18	4	140	11⅜	900	29
20	4¼	150	11¾	1000	30

The combined properties of gravity and fluidity vhich water possesses render it so available as a ource of motive power; *gravity* being the property y which the power is produced, and *fluidity* that y which it is so commodiously qualified to the arious modifications in which it is employed.

Water, it is ascertained, is subject to the same laws f gravity as those of solid bodies, and thereby ac- umulates velocity or effect in an equal ratio when alling though an equal space, or descending from an qual height: hence the velocity attained is as the square root of the height of its fall; and it is now quite satisfactorily decided, that because of the non-elastic property of water, its greatest effect is obtained when acting by gravity throughout its whole height, whether it be applied on a water-wheel, turbine, or other machine, through which circular motion is to be the immediate result.

In regard to *Water-Wheels* and other Machines through which motion is produced by the effort of water, considerable discrepancy of opinion formerly existed, both as to form and velocity, besides other essential points requisite in gaining a maximum of effect with the least possible strain; but these doubts are now in a great measure removed through experiments by the Franklin Institute in America, added to those in France by Morin, and the results of a patented machine by Whitelaw and Stirrat, Scotland, combined with pertinent observations and remarks by interested parties in this as well as in other countries: hence have been deduced the following demonstrative conclusions.

1. That to gain a maximum of effect by a horizontal water-wheel, the water must be laid upon the wheel on the stream side, and the diameter of the wheel so proportioned to the height of the fall, that the water may be laid on about 52¾ degrees distant from the summit of the wheel; or the height of the fall being 1, the height or diameter of the wheel equal 1·108.

2. That the periphery of a water-wheel ought to move at a velocity equal to about twice the square root of the fall of the water in feet per second, and the number of buckets equal 2·1 times the wheel's diameter in feet; also, that precautionary means be adopted for the escape of the air out of the buckets,

either by making the stream of water a few inches narrower than the wheel, or otherwise.

3. That because of water producing a less efficient power by impulse than gravity, turbines, or machines through which the motion is obtained by reaction, are greatly preferable to undershot, or low breast wheels.

4. That a head* of water is required sufficient to cause the velocity of its flowing to be as 3 to 2 of the wheel; $\frac{1}{9}$th of the wheel's diameter being an approximate height, near enough for practical purposes.

5. That the effective power of a wheel constructed according to these restrictions is equal to the product of the number of cubic feet, and velocity in feet per minute, multiplied into ·001325.

Example for general illustration.

Suppose a fall of water 25 feet in height, over which is delivered 112 cubic feet per minute; required the various peculiar requisites for a wheel to be in accordance with the preceding rules.

1st. $25 \times 1{\cdot}08 = 27$ feet, the wheel's diameter.

2nd. $\sqrt{25} \times 2 = 10$ feet, velocity of the wheel in ft. per second. Also $27 \times 2{\cdot}1 = 56{\cdot}7$, say 57 buckets.

3rd. $27 \div 9 = 3$ feet, head of water required.

4th. $112 \times 10 \times 60 \times {\cdot}001325 = 89$ horses' power.

The *turbine* of Fourneyron, in France, and the patented *Water-Mill* of Whitelaw and Stirrat, Scotland, have of late years attracted a considerable share of public attention, their simplicity of construction and asserted effects in like situations being equal to those of the best applied water-wheels. In their manner of construction, they differ, but in principle they are the same; the action of each being created by a centrifugal and tangential force, caused by the weight or impulsion of a column of water whose height or altitude is equal to twice the height of the fall due to the water's velocity; and in order to produce a maximum of effect in either the one or the other by the pressure and centrifugal force of the effluent water, it is necessary that the emitting tubes, or helical channels of the machine, be so curved that the apertures shall be in a right line with the radius of the wheel.

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* *By head is* meant the distance from the surface of the *water to that* point at which it strikes upon the wheel.

In 1838 a number of experiments were made in France by Morin, with a view to the more general introduction of turbines, and a positive proof of their merited qualities in preference to wheels of impulse, which terminated considerably in favour of turbines, and from which the following deductions were made.

1. That turbines are equally adapted to great as to small falls of water.

2. That they are capable of transmitting a useful effect to from 70 to 78 per cent. of the absolute power.

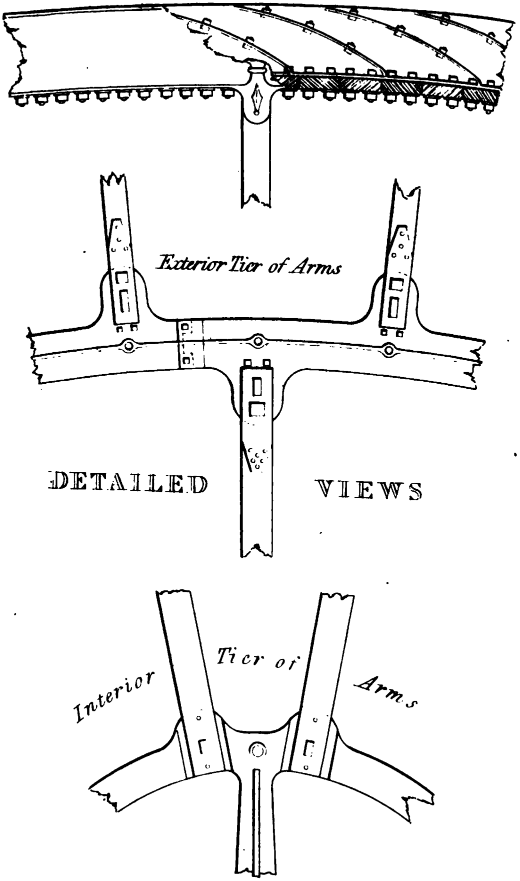
3. That their velocities may vary very considerably from the maximum effect, without differing very sensibly from it.

4. That they will work nearly as effectually when drowned to the depth of 5 or 6 feet, as when free, and consequently, they will make use of the whole of the fall when placed below the level of extreme low water.

5. That they may receive variable quantities of water without altering the ratio of the power to the effect. Corresponding results have also been realized by Whitelaw and Stirrat's machine: hence what is said of the one is equally applicable to the other.

General Rule by Mr. Whitelaw, whereby to compute the power of their Turbine, or Water-Mill.

Rule.—Multiply the effective quantity of water flowing in cubic feet per minute by the height of the fall of the water in feet, and divide the product by 700;



DETAILED VIEWS

John Weale, 59, High Holborn, 1858.

the quotient equal the effect produced in horses' power.

Ex. Required the power produced by 1400 cubic feet per minute over a fall of 30 feet.

$$\frac{1400\times30}{700}=60 \text{ horses' power.}$$

Plates G and H exhibit miniature views of a ponderous overshot water-wheel, chiefly of wrought iron, and in which novelty of construction, immense diameter, and great efficiency, have rendered it an object of universal interest throughout the district in which it is situated : its nominal power is that of 30 horses, but upwards of 40 of indicated resistance seems not materially to diminish its velocity ; and no doubt, on account of the improved form of the buckets, the greatest amount of the water's effect is obtained.

TABLE OF THE RADII OF WHEELS, FROM TEN TO THREE HUNDRED TEETH, THE PITCH* BEING TWO INCHES.

BY B. DONKIN, ESQ., CIVIL ENGINEER, LONDON.

No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.
10	3·236	20	6·392	30	9·567	40	12·746	50	15·926
11	3·549	21	6·710	31	9·885	41	13·064	51	16·244
12	3·864	22	7·027	32	10·202	42	13·382	52	16·562
13	4·179	23	7·344	33	10·520	43	13·700	53	16·880
14	4·494	24	7·661	34	10·838	44	14·018	54	17·198
15	4·810	25	7·979	35	11·156	45	14·336	55	17·517
16	5·126	26	8·296	36	11·474	46	14·654	56	17·835
17	5·442	27	8·614	37	11·792	47	14·972	57	18·153
18	5·759	28	8·931	38	12·110	48	15·290	58	18·471
19	6·076	29	9·249	39	12·428	49	15·608	59	18·789

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* By the pitch is understood the distance between the centres of two contiguous teeth ; and by the radius is understood the distance between the centre of the wheel and the centre of each tooth. For any *other pitch, say, as* two inches is to the radius in the table, so is *the given pitch to the radius* required.

TABLE OF THE RADII OF WHEELS—*continued.*

No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No. of teeth.	Radius in inches.	No of teeth.	Radius in inches.
60	19·107	109	34·700	157	49·978	205	65·256	253	80·534
61	19·425	110	35·018	158	50·296	206	65·574	254	80·853
62	19·744	111	35·337	159	50·615	207	65·893	255	81·171
63	20·062	112	35·655	160	50·933	208	66·211	256	81·489
64	20·380	113	35·974	161	51·251	209	66·529	257	81·808
65	20·698	114	36·292	162	51·569	210	66·848	258	82·126
66	21·016	115	36·611	163	51·888	211	67·166	259	82·444
67	21·335	116	36·929	164	52·206	212	67·484	260	82·763
68	21·653	117	37·247	165	52·524	213	67·803	261	83·081
69	21·971	118	37·565	166	52·843	214	68·121	262	83·399
70	22·289	119	37·883	167	53·161	215	68·439	263	83·717
71	22·607	120	38·202	168	53·479	216	68·757	264	84·036
72	22·926	121	38·520	169	53·798	217	69·075	265	84·354
73	23·244	122	38·838	170	54·116	218	69·394	266	84·673
74	23·562	123	39·156	171	54·434	219	69·712	267	84·991
75	23·880	124	39·475	172	54·752	220	70·031	268	85·309
76	24·198	125	39·793	173	55·071	221	70·349	269	85·627
77	24·517	126	40·111	174	55·389	222	70·667	270	85·946
78	24·835	127	40·429	175	55·707	223	70·985	271	86·264
79	25·153	128	40·748	176	56·026	224	71·304	272	86·582
80	25·471	129	41·066	177	56·344	225	71·622	273	86·900
81	25·790	130	41·384	178	56·662	226	71·941	274	87·219
82	26·108	131	41·703	179	56·980	227	72·258	275	87·537
83	26·426	132	42·021	180	57·299	228	72·577	276	87·855
84	26·741	133	42·339	181	57·617	229	72·895	277	88·174
85	27·063	134	42·657	182	57·935	230	73·214	278	88·492
86	27·381	135	42·976	183	58·253	231	73·532	279	88·810
87	27·699	136	43·294	184	58·572	232	73·850	280	89·129
88	28·017	137	43·612	185	58·890	233	74·168	281	89·447
89	28·336	138	43·931	186	59·209	234	74·487	282	89·765
90	28·654	139	44·249	187	59·527	235	74·805	283	90·084
91	28·972	140	44·567	188	59·845	236	75·123	284	90·402
92	29·290	141	44·885	189	60·163	237	75·441	285	90·720
93	29·608	142	45·204	190	60·482	238	75·760	286	91·038
94	29·927	143	45·522	191	60·800	239	76·078	287	91·357
95	30·245	144	45·840	192	61·118	240	76·397	288	91·675
96	30·563	145	46·158	193	61·436	241	76·715	289	91·993
97	30·881	146	46·477	194	61·755	242	77·033	290	92·312
98	31·200	147	46·795	195	62·073	243	77·351	291	92·630
99	31·518	148	47·113	196	62·392	244	77·670	292	92·948
100	31·836	149	47·432	197	62·710	245	77·988	293	93·267
101	32·155	150	47·750	198	63·028	246	78·306	294	93·585
102	32·473	151	48·068	199	63·346	247	78·625	295	93·903
103	32·791	152	48·387	200	63·665	248	78·943	296	94·222
104	33·109	153	48·705	201	63·983	249	79·261	297	94·540
105	33·427	154	49·023	202	64·301	250	79·580	298	94·858
106	33·746	155	49·341	203	64·620	251	79·898	299	95·177
107	34·064	156	49·660	204	64·938	252	80·216	300	95·495
108	*34·382*								

PRICES OF MILL WORK, MACHINERY, AND LABOUR,

APPROXIMATELY VARYING,

WITH THE PRICES OF IRON AND OF LABOUR.

		£	s.	d.
Mill,				
Bean, from 3*l.* 13*s.* 6*d.* to	each	6	16	6
Bone, for crushing bones, to crush 3 tons per day	do.	105	0	0
Ditto 4 ditto	do.	125	0	0
Ditto 5 ditto	do.	150	0	0
Ditto 6 ditto	do.	165	0	0
Ditto 7 ditto	do.	180	0	0
Ditto 8 ditto	do.	210	0	0
Ditto 9 ditto	do.	220	0	0
Ditto 10 ditto	do.	250	0	0
Brick, including the horse's wheel and every requisite for making large quantities in little time, about,	each	1200	0	0
Bruising, for corn, malt, pulse, &c.	do.	8	8	0
Coffee	do.	1	5	0
Corn, Indian, small size, with two handles	do.	2	10	0
Corn, Indian, large, with fly wheel	do.	5	15	6
Corn, Indian, with cast iron bed and runner, machinery, &c., complete	each	180	0	0
Corn, 4-horse power, with stones 3 feet 2 inches diameter, not including the horse wheel	each	140	0	0
Corn, including the horse wheel	do.	310	0	0
Drug, with the machinery complete for ditto	do.	180	0	0
Flour, *the improved family mill*, with French burr stones, for grinding flour by hand	each	18	18	0
Flour, &c., to work by horse	do.	25	0	0
Flour, portable, 15 inches square	do.	6	6	0
Furze or gorst, from 6*l.* 6*s.* to	do.	10	10	0
Irish wheat	do.	4	4	0
Kibbling, with fly wheels, with or without frames, from 2*l.* 10*s.* to	each	5	10	0
Lead, with cast iron bed, 7 feet 9 inches long, and 3 feet 2 inches wide, rollers 5 feet long, and 12 inches diameter, with square threaded screws, and the whole of the machinery complete, except the power	each	1000	0	0
Linseed, with two rollers 5 feet long, and 12 inches diameter, fitted up with spur pinions, brasses, set screws, cast iron frame, &c.	each	65	0	0
Malt, with fly wheel	do.	6	0	0
do. of 1-horse power	do.	16	16	0
***Pug**, of 2-horse* power, for making bricks, &c.	do.	42	0	[illegible]

Mill,		£	s.	d.
Saw, an upright saw mill, with frame and shifting do., guide rods, brasses, and guides, spindles, rollers, ratchett wheel, rods, catch, &c., connecting rod, brasses, set of saws, buckles, &c., for cutting deals, not including the power, about	each	180	0	0
Saw, do., for planks, &c.	do.	230	0	0
do. do. for cutting timber 2 feet deep, about	do.	450	0	0
do. do. 3 feet deep	do.	570	0	0
Circular saw, with cast iron frame and bench, sliding rule, bearings, rigger, extra carriage, clutch, and lever, including a set of saws, do. do.	each	100	0	0
For cutting veneers, 12 feet diameter	do.	600	0	0
For cross cutting, round or square timber, upon the principle of the stone mill, framed, with three spur wheels, &c.	each	150	0	0
Steel, for wheat, barley, oats, peas, beans, &c.	do.	3	13	6
do. do. do.	do.	6	16	6
Sugar, cattle, for the West Indies, &c. The rollers in a strong iron frame, 5 feet long, and 2 feet diameter, to work in a horizontal position, including the machinery to work the mill, with the wood arms, sweeps, &c., for the cattle to draw from, complete	each	670	0	0
rollers, 4½ feet long, and 2 feet diameter	do.	610	0	0
do. 4 do. 1⅔ do.	do.	560	0	0
do. 3½ do. 1½ do.	do.	525	0	0
do. 3 do. 1½ do.	do.	450	0	0
Sugar, for a steam engine,				
rollers, 5 feet long, and 2 feet diameter	do.	510	0	0
do. 4½ do. 2 do.	do.	485	0	0
do. 4 do. 2 do.	do.	420	0	0
do. 3½ do. 2 do.	do.	375	0	0
do. 3 do. 2 do.	do.	325	0	0
The machinery for connecting the engine to the mill, for working it, in addition	each	210	0	0
Sugar, for a windmill,				
rollers, 5 feet long, and 2 feet diameter	do.	510	0	0
do. 4½ do. 2 do.	do.	480	0	0
do. 4 do. 2 do.	do.	420	0	0
do. 3½ do. 2 do.	do.	370	0	0
do. 3 do. 2 do.	do.	320	0	0
A pair of wheels to connect the spindle of windmill to the sugar mill, will be, in addition to the foregoing	each	75	0	0
Sugar, for a water wheel,				
rollers, 5 feet long, and 2 feet diameter	do.	500	0	0
do. 4½ do. 2 do.	do.	480	0	0
do. 4 do. 2 do.	do.	420	0	0
do. 3½ do. 2 do.	do.	370	0	0
do. 3 do. 2 do.	do.	320	0	0
The machinery to connect the shaft of the water wheel, will be, in addition to the above to each mill	each	180	0	0
The rollers in an iron frame, 3 feet long, and 2 feet diameter, to work in a vertical position	each	460	0	0

		£	s.	d.
MILL,				
Sugar, for a water wheel,				
rollers, 3 feet long, and 1 foot 10 in. diameter,	each	430	0	0
do. 3 feet long, and 1 foot 8 inches do.	do.	400	0	0
do. 2 feet 10 in. long, and 2 feet do.	do.	450	0	0
do. 2 ft. 10 in. long, and 1 ft. 10 in. do.	do.	420	0	0
do. 2 ft. 10 in. long, and 1 ft. 8 in. do.	do.	400	0	0
do. 2 feet 8 inches long, and 2 ft. do.	do.	440	0	0
do. 2 ft. 8 in. long, and 1 ft. 10 in. do.	do.	410	0	0
do. 2 ft. 8 in. long, and 1 ft. 8 in. do.	do.	380	0	0
do. 2 feet 6 inches long, and 2 ft. do.	do.	430	0	0
do. 2 ft. 6 in. long, and 1 ft. 10 in. do.	do.	400	0	0
do. 2 ft. 6 in. long, and 1 ft. 8 in. do.	do.	370	0	0
Wheat, from 3*l.* 3*s.* to	do.	20	0	0
portable, 15 inches square	do.	6	6	0
do. with bolting machine attached	do.	10	10	0
do. patent hand, with French burrstones	do.	18	18	0
do. for 1-horse power	do.	31	0	0
MILLSTONE,				
Specific gravity, per foot cube, 157 lbs.				
French burr, 2 ft. 2 in. diam., flat way of the burrs,	per pair	20	0	0
do. 3 feet diameter	do.	30	0	0
do. 4 feet diameter	do.	36	0	0
do. 4 feet diameter, bedstone, flat, and the runner edgeway of the burrs	per pair	50	0	0
do. 4 feet 6 inches in diameter	do.	60	0	0
do. 5 feet diameter	do.	70	0	0
malt cologne, 3 ft. diameter, and 5 in. thick	do.	3	13	6
making ditto	per stone	3	3	0
do. 2 feet 8 inches	per pair	2	12	6
do. 2 feet 6 inches	do.	2	0	0
moor edge stones, 4 feet	do.	24	0	0
bed stone to ditto	each	10	10	0
4 feet 6 inches	per pair	27	0	0
bed stone to ditto	each	11	0	0
5 feet	per pair	30	0	0
bed stone to ditto	each	12	12	0
5 feet 6 inches	per pair	38	0	0
bed stone to ditto	each	13	13	0
6 feet	per pair	50	0	0
bed stone to ditto	each	14	14	0
peak, 3 feet diameter	per pair	18	0	0
do. 3 feet 6 inches diameter	do.	21	0	0
do. 4 feet do.	do.	24	0	0
do. 4 feet 6 inches do.	do.	27	0	0
do. 5 feet do.	do.	30	0	0
MILLWRIGHT'S WORK,				
Millwright, per day		0	8	4
Colour mill work,				
a hand colour mill, stones 18 or 20 ins. diam., with an oak frame, two iron cog wheels, two spindles, a fly wheel, handle, tub, scraper, iron hopper, &c.,	each	22	10	0
Corn mill work,				
a full sized bolting mill, including reel, pannel case, pannels, beaters, iron and brass work	each	31	10	0
a reel with shaft hoop, gudgeons, and iron work	do.	4	4	0
prepared beech beaters	per foot run	0	1	0

		£	s.	d.
MILLWRIGHT'S WORK,				
Corn mill work,				
a machine cylinder, 4 feet long, and 18 inches diameter, exclusive of wire	each	8	8	0
brushes, rings, spindles, and beaters	do.	11	11	0
a cylinder 5 feet long, exclusive of wire	do.	16	16	0
brushes, spindles, &c.	do.	12	12	0
a machine case to a 5 feet cylinder	do.	22	10	0
a cylinder 6 feet long, and 18 inches diameter	do.	25	0	0
a hoop, hopper, shoe, and ladder for 4 ft. stones	do.	9	9	0
ditto for 5 feet ditto	do.	10	10	0
ditto for malt mill stones	do.	7	7	0
a hoop for 4 feet stones	do.	4	0	0
ladder for ditto	do.	1	4	0
shoe for ditto	do.	0	14	0
inch elm hopper for ditto	do.	1	9	0
damsels	do.	1	1	0
steel mill bills	per lb.	0	2	0
Mustard mill work, for a pair of cast iron carriages, brasses, and set of screws to ditto for rollers		11	11	0
turning a pair of rollers when out of order		3	15	0
Oil mill work,				
a rough cast iron oil press	per cwt.	1	5	0
wood stampers	each	3	3	0
a pair of cast iron rollers 2 feet 2 inches long, 12½ inches diameter, solid, with cast iron carriages, brasses, bolts, &c.	per pair	84	0	0
turning a pair of old rollers and chipping down the pinions		5	5	0
Patterns for wheels above 18 inches diameter, width of cog 1 inch	per foot diameter	1	18	0
2 inches	do.	2	2	0
3 do.	do.	2	4	0
4 do.	do.	2	8	0
5 do.	do.	2	14	0
6 do.	do.	3	0	0
7 do.	do.	3	8	0
8 do.	do.	4	0	0
9 do.	do.	4	16	0
10 do.	do.	5	5	0
11 do.	do.	5	15	0
12 do.	do.	6	0	0
All patterns under 18 inches to be charged extra.				
for rigger wheels, to be charged less than wheels pr. ft.		0	8	0
for ratchett wheels	do.	0	8	0
Pipe, cast iron, of 2 inch bore	per yard	0	3	9
do. 3 do.	do.	0	4	9
do. 4 do.	do.	0	6	0
do. 5 do.	do.	0	8	6
do. 6 do.	do.	0	9	6
do. 7 do.	do.	0	11	6
do. 8 do.	do.	0	15	0
do. 9 do.	do.	1	2	0
do. 10 do.	do.	1	5	0
do. 11 do.	do.	1	8	0
do. 12 do.	do.	1	13	0
curved pipes, from 16s. to	per cwt.	0	18	0

THE WEIGHT OF CAST IRON PIPES 12 INCHES LONG.

Diameter of bore.	Thickness.								
	¼-in.	⅜-in.	½-in.	¾-in.	1-in.	1¼-in.	1½-in.	1¾-in.	2-in.
in.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·05	5·85	7·35	12·9	19·7	—	—	—	—
1½	4·28	6·9	10·6	16·6	24·4	—	—	—	—
2	5 5	8·7	12·2	20·2	29·25	39·5	—	—	—
2½	6·73	10·5	14·6	23·5	34·2	46·6	—	—	—
3	7·95	12·5	17·1	27·4	39·0	51·75	—	—	—
3½	9·15	14·25	19·5	31·0	43·9	58·0	—	—	—
4	10·4	16·0	22·0	34·7	48·8	64·75	80·5	—	—
4½	11·62	17·9	24·4	38·3	53·7	70·5	87·5	—	—
5	12·8	20·	26·8	42·0	58·6	76·3	95·4	—	—
5½	..	21·8	29·3	45·6	63·5	82·5	103·0	—	—
6	..	23·6	31·75	49·5	68·5	88·2	110·0	133·	156·
6½	..	25·4	34·2	52·8	73·2	94·6	117·0	141·	166·
7	..	27·	36·5	56·6	78·0	101·0	125·0	150·	176·
7½	..	28·8	39·	60·3	83·0	107·0	132·0	158·	186·
8	..	31·0	41·4	64 0	87·5	112·8	139·	166·	196·
8½	..	..	43·8	67·5	92·4	119·	146·	175·	206·
9	..	..	46·3	71 2	97·5	125·	154·	183·	216·
9½	..	..	48·6	74·8	102·5	131·	161·	192·	226·
10	..	..	51·1	78·5	107·	137·	169·	200·	236·
10½	..	..	53·6	82·5	112·4	143·	176·	209·	246·
11	..	..	56·2	86·0	117·0	149·	183·	217·	255·
11½	..	..	58·5	89·5	122·	155·	191·	227·	265·
12	..	..	61·0	93·5	127·	161·	198·	235·	275·
12½	..	..	63·5	97·3	132·	167·	205·	243·	285·
13	..	..	66·0	101·0	137·	173·5	212·	252·	294·
13½	..	..	68·4	104 8	141·5	179·	219·	260·	304·
14	..	.	71·0	108·2	146·	185·	227·	269·	314·
14½	..	..	73·4	112·3	151·	192·	234·	277·	324·
15	..	..	75·8	115·7	156·	198·	242·	286·	334·
15½	..	..	78·1	119·0	161·	204·	250·	295·	344·
16	..	..	80·7	123·	166·	211·	257·	303·	353·
16½	..	..	83·1	126·5	170·5	217·	264·	312·	363·
17	..	..	85·5	130·	175·5	223·	271·	322·	373·
17½	..	..	87·8	133·5	180·5	229·	278·	330·	383·
18	..	..	90·5	137·	185·	235·	285·	338·	393·
18½	..	..	93·0	140·5	190·	241·	293·	347·	402·
19	..	..	95·5	144·8	195·	247·	300·	354·	412·
19½	..	..	97·8	148·5	200·	253·	307·	363·	422·
20	..	..	100·0	152·	205·	259·	315·	372·	432·
20½	..	..	102·5	156·	210·	265·	323·	381·	442·
21	..	..	105·0	159·5	215·	271·	330·	390·	452·
21½	..	..	107·5	163·	220·	277·	337·	398·	461·
22	..	..	110·0	166·5	226·	283·	344·	408·	471·

Millwright's Work,		£	s.	d.
Pipe, cast iron,				
for rain water	per yard	0	5	0
fountain heads for ditto	each	0	5	0
copper	per lb.	0	1	9
small or crooked	do.	0	2	2
tinned inside and out, 1¼ inch	per foot	0	2	0
do. 1½ do.	do.	0	2	6
do. 2 do.	do.	0	3	0
do. 2½ do.	do.	0	4	0
elm, 2 inches diameter	per yard	0	3	0
3 do.	do.	0	3	8
4 do.	do.	0	4	10
5 do.	do.	0	6	0
6 do.	do.	0	8	6
7 do.	do.	0	9	6
8 do.	do.	0	13	8
9 do.	do.	0	17	0
lead, ½ inch, cast	per foot	0	0	7
¾ do.	do.	0	0	10
1 do.	do.	0	1	6
1¼ do.	do.	0	1	10
1½ do.	do.	0	2	3
2 do.	do.	0	3	0
3 inch, milled	do.	0	2	6
3½ do.	do.	0	3	0
4 do.	do.	0	4	0
4½ do.	do.	0	5	0
5 do.	do.	0	6	0
5½ do.	do.	0	7	0
1¼ inch, soldered	do.	0	1	6
1½ do.	do.	0	2	0
2 do.	do.	0	3	0

Patent lead pipe,

Bore.	Common.		Middling.		Strong.	
Inch.	s.	d.	s.	d.	s.	d.
½	0	4	0	0	0	0
⅝	0	5½	0	0	0	0
¾	0	6½	0	7½	0	8½
1	0	9½	0	11½	1	0
1¼	1	0	1	2	1	3
1½	1	3	1	5	1	6
1¾	1	6	1	8	1	10
2	2	0	2	3	2	6
2½	2	6	2	10	3	2
3	3	2	3	6	4	0

Steam pipe. The steam pipe of an engine generally consists of the twenty-fourth part of the cylinder; for instance, the cylinder 26 inches diameter, thus: 26 × 26 = 676 × ·7854 = 530·9304; area of the cylinder,

					£	s.	d.
Millwright's Work,							
Steam pipe, &c., 530 inches. The pipe 5 inches diameter, then 5 × 5 = 25 × ·7854 = 19·6350, 19·5 × 24 = 468.							
from this it will appear, that a cylinder of 25 inches diameter, will require the steam pipe to be 5 inches diameter, or thereabouts.							
Plummer blocks of cast iron, with ditto caps, two bolts to each, fitted to the bearings turned on the shafts, pattern included.							
diameter of bearing,	1½	inches	...	per inch in width	1	1	0
do.	2	do.	....	do.	1	1	0
do.	2½	do.	....	do.	1	1	0
do.	3	do.	....	do.	1	1	0
do.	3½	do.	....	do.	1	1	0
do.	4	do.	....	do.	1	5	0
do.	4½	do.	....	do.	1	5	0
do.	5	do.	....	do.	1	5	0
do.	5½	do.	....	do.	1	5	0
do.	6	do.	....	do.	1	7	0
do.	6½	do.	....	do.	1	7	0
do.	7	do.	....	do.	1	10	0
do.	7½	do.	....	do.	1	10	0
do.	8	do.	....	do.	1	10	0
do.	8½	do.	....	do.	1	10	0
do.	9	do.	....	do.	1	10	0
do.	9½	do	....	do.	1	10	0
do.	10	do.	....	do.	1	15	0
do.	10½	do.	....	do.	1	15	0
do.	11	do.	....	do.	2	0	0
do.	11½	do.	....	do.	2	0	0
do.	12	do.	....	do.	2	2	0

Shafts of cast iron,

Diameter of bearing.	Per inch superficial, collars included.		Per inch in length between collars, the collars included.		Per bearing, the length equal to the diameter.		
Inches.	s.	d.	s.	d.	£	s.	d.
2	0	3½	4	6	0	9	0
3	0	3	4	6	0	13	6
4	0	2½	4	10½	0	17	6
5	0	2¼	5	3	1	6	3
6	0	2¼	5	8	1	14	0
7	0	2¼	6	1	2	2	4
8	0	2¼	6	9	2	14	3
9	0	2¼	7	4	3	5	7
10	0	2¼	7	11	3	19	3
11	0	2¼	8	6	4	3	9
12	0	2¼	9	2	4	8	3

MILLWRIGHT'S WORK, £ s. d.

Shafts, weight of, &c., square and round in cast iron, per foot run:

	SQUARE.	ROUND.
2 ins.	13 lbs.	10½ lbs.
2¼	16	13
2½	20	15½
2¾	24	18½
3	28	22½
3¼	33	26½
3½	38	31½
3¾	44	35½
4	50	40
4¼	57	45½
4½	64	51
4¾	71	56½
5	78	62
5¼	86	69
5½	94	76
5¾	103	83
6	112	90
6¼	122	98
6½	132	107
6¾	142	115
7	153	124
7¼ ins.	165 lbs.	133 lbs.
7½	177	142
7¾	188	151
8	200	160
8¼	213	170
8½	226	180
8¾	239	190
9	252	200
9¼	267	212
9½	282	224
9¾	297	237
10	312	250
10¼	331	265
10½	350	280
10¾	369	295
11	388	310
11¼	407	325
11½	426	340
11¾	445	356
12	464	372

		£	s.	d.
shafts, up to 2 inches, square or round, with two bearings, turned	per lb.	0	0	6
2 inches to 2½ inches	do.	0	0	5½
2½ do. 4 do.	do.	0	0	5
4 do. 6 do.	do.	0	0	4½
6 do. 9 do.	do.	0	0	4
9 do. 12 do.	do.	0	0	3½

Where shafts are turned extra, or in addition to the bearing at each end, for the plummer blocks, such additional turned part must be measured and charged at 1¾*d.* per inch, in addition to the price of the shaft.

Shafts, of wood,

		£	s.	d.
elm, of all sizes	per foot cube	0	8	6
fir do.	do.	0	7	0
oak, up to 18 inches	do.	0	9	0
ditto 2 feet	do.	0	11	0

the above includes mortising and letting in the gudgeons.

measure the largest part of the wood shaft for the charging dimension.

		£	s.	d.
staves, turned	per foot run	0	1	6
wallowers, with staves	per foot diameter	3	17	0
wash wheels, the rings, arms, and sides of elm, ribs of fir, 6 ft. diam., and 4 ft. wide	per foot diam.	5	5	0
ditto ditto 7 feet diam.	do.	5	10	0
wood horse yokes, of 4-inch elm	per pair	1	10	0

Water wheel work,

		£	s.	d.
elm rings, from 4½ to 5 inches thick, with oak griped arms to ditto	per foot diam.	2	0	0
oak rings from 4½ to 5 in. thick, &c.	do.	2	10	0

	£	s.	d.
LWRIGHT'S WORK,			
Water wheel work, &c.,			
oak starts, 3½ by 2 .... per foot run	0	1	6
floats and back boards of elm, prepared to size per foot super.	0	0	10
over shot wheels, rings, and arms ready made, the rings 8 in. wide and 3 in. thick .. per foot diam.	2	7	0
elm sole boards, risers, and buckets, per foot super.	0	0	10
wrought iron floats bent to order..... .... per lb.	0	0	10
Wheels, bevel, of wood, for the bevel, charge additional per foot	0	5	0
windmill brakes, 9 inches wide......per foot diam.	1	15	0
maltmill heads, with staves .... do.	3	0	0
wallowers, with ditto .... do.	3	17	0
spur nuts of elm, of 2 to 4 inch plank do.	3	10	0

the cogs, in all cases, to be charged extra.

Wheels, of cast iron, both tooth and mortis, geared, pitched, chipped and filed, the pattern included in the price.

width of cog,	pr. ft. diam.			width of cog,	per ft. diam.		
1 inch	£3	3	0	8¾ inches......	11	12	6
1¼	3	5	0	9	12	0	0
1½	3	10	0	9¼	12	5	0
1¾	3	15	0	9½	12	10	0
2	4	0	0	9¾	12	15	0
2¼	4	5	0	10	13	0	0
2½	4	10	0	10¼	13	5	0
2¾	4	15	0	10½	13	10	0
3	5	0	0	10¾	13	15	0
3¼	5	5	0	11	14	0	0
3½	5	10	0	11¼	14	10	0
3¾	5	15	0	11½	15	0	0
4	6	0	0	11¾	15	10	0
4¼	6	7	6	12	16	0	0
4½	6	15	0	12¼	17	0	0
4¾	7	2	6	12½	18	0	0
5	7	10	0	12¾	19	0	0
5¼	7	12	6	13	20	0	0
5½	7	15	0	13¼	20	10	0
5¾	7	17	6	13½	21	0	0
6	8	0	0	13¾	21	10	0
6¼	8	5	0	14	22	0	0
6½	8	10	0	14¼	22	10	0
6¾	8	15	0	14½	23	0	0
7	9	0	0	14¾	23	10	0
7¼	9	7	6	15	24	0	0
7½	9	15	0	15¼	24	10	0
7¾	10	2	6	15½	25	0	0
8	10	10	0	15¾	25	10	0
8¼	10	17	6	16	26	0	0
8½	11	5	0				

Wheels, lantern, made solid, and fitted together in two pieces, or halves, with wrought iron hoops and copper screws, &c.

	£	s.	d.
7 inches deep over all .... per foot diam.	7	0	0
8 do. .... do.	8	0	0
9 do. .... do.	9	0	0

MILLWRIGHT'S WORK,			£	s.	d.
Wheels, &c.,					
10 inches deep over all	....	per foot diam.	10	0	0
11 do.	....	do.	11	0	0
12 do.	....	do.	12	0	0
13 do.	....	do.	13	0	0
14 do.	....	do.	14	0	0
Wheels, overshot water, all of iron.					
a wheel 20 feet diameter, and 2 feet wide	....	each	350	0	0
24 do. do.	....	do.	420	0	0
28 do. do.	....	do.	470	0	0
32 do. do.	....	do.	535	0	
36 do. do.	....	do.	585	0	
for a wheel 2 feet wide	....	per foot diam.	16	16	0
do. 2 feet 3 inches wide	....	do.	18	18	0
do. 2 6 do.	....	do.	21	0	0
do. 2 9 do.	....	do.	23	2	0
do. 3 0 do.	....	do.	25	4	0
do. 3 3 do.	....	do.	27	6	0
do. 3 6 do.	....	do.	29	8	0
do. 3 9 do.	....	do.	31	10	0
do. 4 0 do.	....	do.	33	12	0
do. 4 3 do.	....	do.	35	14	0
do. 4 6 do.	....	do.	37	16	0
do. 4 9 do.	....	do.	40	0	0
do. 5 0 do.	....	do.	42	0	0
do. 5 3 do.	....	do.	44	2	
do. 5 6 do.	....	do.	46	4	
do. 5 9 do.	....	do.	48	6	
do. 6 0 do.	....	do.	50	8	

The millwright's table for water wheels,

Height of the fall of Water.	Velocity of the fall of Water per second.	Velocity of the Wheel per second.	Revolution of the Wheel per minute.
Feet.	ft. dec.	ft. dec.	rev. dec.
1	8·02	2·67	2·83
2	11·34	3·78	4·00
3	13·89	4·63	4·91
4	16·04	5·35	5·67
5	17·93	5·98	6·34
6	19·64	6·55	6·94
7	21·21	7·07	7·50
8	22·68	7·56	8·02
9	24·05	8·02	8·51
10	25·35	8·45	8·97
11	26·59	8·86	9·40
12	27·27	9·26	9·82
13	28·91	9·64	10·22
14	30·00	10·00	10·60
15	31·05	10·35	10·99
16	32·07	10·79	11·34
17	33·06	11·02	11·70
18	34·02	11·34	12·02
19	34·96	11·65	12·37
20	35·86	11·95	12·68

		£	s.	d.
Millwright's Work,				
Wheels, tread 4 feet 6 inches diameter	per foot	2	10	0
do. 5 feet do.	do.	3	3	0
Wheels, wood,				
a horse wheel of any diameter, 4 in. thick	do.	2	14	0
do. 5 do.	do.	3	0	0
do. 6 do.	do.	3	6	0
do. 7 do.	do.	3	12	0
do. 8 do.	do.	3	18	0
the cogs, truss, arms, and braces, to be charged for extra.				
a horse wheel, including shaft, ground frame, yokes, cogs, braces, the iron and brass work, together with the labour of fixing and gearing, will amount to (according to the degree of strength) from 3*l.* 18*s.* to per foot, for good wheels		10	10	0
a framed wood wheel, exclusive of cogs of elm, from 7 to 9 inches thick, with through arms	per foot	3	18	0
do. griped arms	do.	4	6	0
do. 10 to 12 in. thick, with through arms	do.	4	16	0
do. do. griped arms	do.	5	10	0
Master's charges, &c.				
in attending workmen, giving instructions, exclusive of all reasonable expenses	per day	0	15	0
attending upon arbitrations, exclusive of expenses	per day	2	2	0

upon tradesmen's bills charge 20 per cent. profit upon cast iron as per founder's account; 25 per cent. upon brass ditto; 20 per cent. upon smith's ditto; 10 per cent. to be charged upon all timber provided by the employer.

all land and water carriage to be charged.

but the most regular, approved, and convenient method for ascertaining the price of any single article of work is in the manner following, viz. :—

	£	s.	d.
timber cost	£2	10	0
cast iron	5	0	0
brass	3	15	0
wrought iron	4	0	0
files	0	12	0
sundries	0	7	8
	£16	4	8

	£	s.	d.
The above being the actual cost of the materials used, add, therefore, to	£16	4	8
workmen's time, 12 days, at 7*s.* per day	4	4	0
for the use of tools, 2*s.* per day	1	4	0
for the profit, to this amount add one-fourth, viz.	5	8	2
Amount to Charge	£ 27	0	10

		£	s.	d.
Labour prices only,				
cogs, apple tree, for gearing wheels, up to 3 inches *wide*	each	0	0	2

Millwright's Work,

Labour prices only,

	£	s.	d.
cogs, apple tree, above 3 inches wide, extra per inch in width .... each	0	0	0¾
beech, shanked to 3 inches wide, &c. .. do.	0	0	1½
ditto, above 3 inches wide, extra per inch in width .... each	0	0	0¾
hornbeam, shanked to 3 inches wide, &c. do.	0	0	2¼
ditto, above 3 inches wide, extra per inch in width .... each	0	0	1
oak, shanked as before .... do.	0	0	2¼
ditto, above 3 inches wide, extra per inch in width .... each	0	0	1
foreign live oak, shanked as before .... do.	0	0	4½
ditto, above 3 inches wide, extra per inch in width .... each	0	0	2
for wood wheels, not exceeding 12 in. long, in addition to the foregoing prices .. per inch	0	0	0½
labour, shanking .... each	0	0	3½

patterns for wheels, all above 18 in. diam.,

width of cog,	pr. ft. diam.	width of cog,	per ft. diam.
1 inch	£0 9 6	7¾	0 19 6
1¼	0 9 9	8	1 0 0
1½	0 10 0	8¼	1 0 6
1¾	0 10 3	8½	1 1 4
2	0 10 6	8¾	1 2 2
2¼	0 10 9	9	1 3 0
2½	0 11 0	9¼	1 4 0
2¾	0 11 3	9½	1 5 0
3	0 11 6	9¾	1 6 0
3¼	0 11 9	10	1 7 0
3½	0 12 0	10¼	1 8 0
3¾	0 12 3	10½	1 9 0
4	0 12 6	10¾	1 10 0
4¼	0 12 9	11	1 11 0
4½	0 13 0	11¼	1 12 0
4¾	0 13 6	11½	1 13 0
5	0 14 0	11¾	1 14 0
5¼	0 14 6	12	1 15 0
5½	0 15 0	12¼	1 16 0
5¾	0 15 6	12½	1 17 0
6	0 16 0	12¾	1 18 0
6¼	0 16 6	13	1 19 0
6½	0 17 0	13¼	2 0 0
6¾	0 17 6	13½	2 2 0
7	0 18 0	13¾	2 4 0
7¼	0 18 6	14	2 6 0
7½	0 19 0		

riggers of wood,

	£	s.	d.
above 20 inches diameter, single grooved, and made of 4-inch elm .... per foot diam.	0	4	6
double ditto .... do.	0	4	0
under 18 inches................ do.	0	4	0
double ditto .... do.	0	4	0
under 12 inches................ do.	0	4	0
iron, covered with wood, for straps or ropes per foot diam.	0	10	6

ILLWRIGHT'S WORK, £ s. d.

Labour prices only,

shafts, of cast iron, collars included, per in. sup.,

inches	£	s.	d.	inches	£	s.	d.
2 inches	£0	0	1	5¼ inches	£0	0	0¾
2¼	0	0	1	5½	0	0	0¾
2½	0	0	1	5¾	0	0	0¾
2¾	0	0	1	6	0	0	0¾
3	0	0	0¾	6¼	0	0	0¾
3¼	0	0	0¾	6½	0	0	0¾
3½	0	0	0¾	6¾	0	0	0¾
3¾	0	0	0¾	7	0	0	0½
4	0	0	0¾	7¼	0	0	0½
4¼	0	0	0¾	7½	0	0	0½
4½	0	0	0¾	7¾	0	0	0½
4¾	0	0	0¾	8	0	0	0½
5	0	0	0¾				

		£	s.	d.
shafts of wood, elm, any size	per foot cube	0	2	0
do. fir	do.	0	1	6
do. oak	do.	0	2	6
staves of beech or hornbeam, turned	per foot run	0	0	3
wallowers, with staves	per foot diam.	0	15	0
wash wheels, the rings, arms, and sides of elm, &c., 6 feet diameter, and 4 feet wide	per foot diam.	1	5	0
7 feet ditto ditto	do.	1	7	0
wood horse yokes, of 4-inch elm	per pair	0	7	6
water wheel work, elm rings, from 4½ to 5 inches thick, with oak griped arms to ditto	per ft. diam.	0	10	0
oak rings, from 4½ to 5 inches thick	do.	0	12	6
ditto starts	per foot run	0	0	4
floats and back boards of elm, prepared to size	per foot sup.	0	0	2½
overshot wheels, rings and arms, &c.	per ft. dia.	0	12	0
sole boards, risers, buckets, &c., to ditto	per foot sup.	0	0	2
wheels, bevel of wood, for the bevel charge, in addition	per foot	0	1	6
windmill breaks, 9 inches wide	per foot diam.	0	9	0
maltmill heads with staves	do.	0	15	0
wallowers, with staves	do.	0	18	0
spur nuts, with ditto	do.	0	16	0

wheels of cast iron, tooth and mortis geared, pitched, chipped, and filed, including pattern:—

width of cog,	pr. ft. diam. £	s.	d.	width of cog,	pr. ft. diam. £	s.	d.
2 inches	£1	0	0	5¼ inches	1	18	0
2¼	1	1	0	5½	1	18	6
2½	1	2	0	5¾	1	19	0
2¾	1	3	6	6	2	0	0
3	1	5	0	6¼	2	1	0
3¼	1	6	6	6½	2	2	0
3½	1	8	0	6¾	2	3	0
3¾	1	9	0	7	2	4	0
4	1	10	0	7¼	2	5	0
4¼	1	11	6	7½	2	6	6
4½	1	13	0	7¾	2	8	0
4¾	1	15	0	8	2	10	0
5	1	17	6	8¼	2	12	0

Millwright's Work, £ s. d.

Labour prices only,

width of cog,	pr. ft. diam. £	s.	d.	width of cog,	pr. ft. diam. £	s.	d.
8½ inches....	£2	14	0	11½ inches......	3	15	0
8¾	2	17	0	11¾	3	17	6
9	3	0	0	12	4	0	0
9¼	3	1	6	12¼	4	5	0
9½	3	3	0	12½	4	10	0
9¾	3	4	6	12¾	4	15	0
10	3	6	0	13	5	0	0
10¼	3	7	0	13¼	5	5	0
10½	3	8	0	13½	5	10	0
10¾	3	9	0	13¾	5	15	0
11	3	10	0	14	6	0	0
11¼	3	12	6				

pitching and trimming, including filing, p. in. sup. 0 0 1

measurement to be taken from the pattern, and not from the wheel.

wheels of wood,

	thickness		£	s.	d.
a horse wheel, of any diam.,	4 in. thick,	per foot	0	12	0
do.	5 do.	do.	0	13	6
do.	6 do.	do.	0	15	0
do.	7 do.	do.	0	16	6
do.	8 do.	do.	0	18	0

The cogs to be charged extra.

Effects produced by water in an aëriform state.

When water in a vessel is subjected to the action of fire, it readily imbibes the heat or fluid principle of which the fire is the immediate cause, and sooner or later, according to the intensity of the heat, attains a temperature of 212° Fahrenheit. If at this point of temperature the water be not enclosed, but exposed to atmospheric pressure, ebullition will take place, and steam or vapour will ascend through the water, carrying with it the superabundant heat, or that which the water cannot under such circumstances of pressure absorb, to be retained and to indicate a higher temperature.

Water, in attaining the aëriform state, is thus uniformly confined to the same laws under every degree of pressure; but as the pressure is augmented, so is the indicated temperature proportionately elevated; hence the various densities of steam, and corresponding degrees of elastic force.

of the Elastic Force of Steam, and corresponding perature of the Water with which it is in contact.

ure per re inch, spheric ssure uded.	Elastic Force in		Temperature in Degrees of			Volume of Steam compared with vol. of Water.
	Inches of Mercury.	Metres of Mercury.	Fahr.	Reaum.	Cent.	
kilog.						
6·668	30·00	·762	212·0	80·0	100·0	1711
6·80	30·60	·778	212·8	80·4	100·4	1670
7·26	32·64	·829	216·3	81·9	102·4	1573
7·71	34·68	·880	219·6	83·3	104·2	1488
8·16	36·72	·932	222·7	84·7	105·9	1411
8·62	38·76	·984	225·6	86·0	107·6	1343
9·07	40·80	1·037	228·5	87·3	109·2	1281
9·52	42·84	1·089	231·2	88·5	110·7	1225
9·98	44·88	1·140	233·8	89·7	112·1	1174
10·43	46·92	1·192	236·3	90·8	113·5	1127
10·88	48·96	1·244	238·7	91·9	114·8	1084
11·34	51·00	1·296	241·0	93·0	116·1	1044
11·79	53·04	1·348	243·3	93·9	117·4	1007
12·25	55·08	1·400	245·5	94·9	118·6	973
12·70	57·12	1·452	247·6	95·8	119·8	941
13·15	59·16	1·503	249·6	96·7	120·9	911
13·61	61·21	1·555	251·6	97·6	122·0	883
14·06	63·24	1·607	253·6	98·5	123·1	857
14·51	65·28	1·659	255·5	99·3	124·2	833
14·97	67·32	1·711	257·3	100·1	125·2	810
15·42	69·36	1·763	259·1	100·9	126·2	788
15·87	71·40	1·814	260·9	101·7	127·2	767
16·33	73·44	1·866	262·6	102·5	128·1	748
16·78	75·48	1·918	264·3	103·2	129·1	729
17·23	77·52	1·970	265·9	104·0	129·9	712
17·69	79·56	2·022	267·5	104·7	130·8	695
18·14	81·60	2·074	269·1	105·4	131·7	679
18·59	83·64	2·126	270·6	106·0	132·6	664
19·05	85·68	2·178	272·1	106·7	133·4	649
19·50	87·72	2·229	273·6	107·4	134·2	635
19·96	89·76	2·281	275·0	108·0	135·0	622
20·41	91·80	2·333	276·4	108·6	135·8	610
20·86	93·84	2·385	277·8	109·2	136·6	598
21·32	95·88	2·437	279·2	109·9	137·3	586
21·77	97·92	2·489	280·5	110·4	138·1	575
22·22	99·96	2·541	281·9	111·1	138·8	564
22·68	102·00	2·592	283·2	111·6	139·6	554

MILLWRIGHT'S WORK,

Labour prices only,

		£	s.	d.
cogs, apple tree, above 3 inches wide, extra per inch in width	each	0	0	0¾
beech, shanked to 3 inches wide, &c.	do.	0	0	1½
ditto, above 3 inches wide, extra per inch in width	each	0	0	0¾
hornbeam, shanked to 3 inches wide, &c.	do.	0	0	2¼
ditto, above 3 inches wide, extra per inch in width	each	0	0	1
oak, shanked as before	do.	0	0	2¼
ditto, above 3 inches wide, extra per inch in width	each	0	0	1
foreign live oak, shanked as before	do.	0	0	4½
ditto, above 3 inches wide, extra per inch in width	each	0	0	2
for wood wheels, not exceeding 12 in. long, in addition to the foregoing prices	per inch	0	0	0½
labour, shanking	each	0	0	3½

patterns for wheels, all above 18 in. diam.,

width of cog,	pr. ft. diam.	width of cog,	per ft. diam.
1 inch	£0 9 6	7¾	0 19 6
1¼	0 9 9	8	1 0 0
1½	0 10 0	8¼	1 0 6
1¾	0 10 3	8½	1 1 4
2	0 10 6	8¾	1 2 2
2¼	0 10 9	9	1 3 0
2½	0 11 0	9¼	1 4 0
2¾	0 11 3	9½	1 5 0
3	0 11 6	9¾	1 6 0
3¼	0 11 9	10	1 7 0
3½	0 12 0	10¼	1 8 0
3¾	0 12 3	10½	1 9 0
4	0 12 6	10¾	1 10 0
4¼	0 12 9	11	1 11 0
4½	0 13 0	11¼	1 12 0
4¾	0 13 6	11½	1 13 0
5	0 14 0	11¾	1 14 0
5¼	0 14 6	12	1 15 0
5½	0 15 0	12¼	1 16 0
5¾	0 15 6	12½	1 17 0
6	0 16 0	12¾	1 18 0
6¼	0 16 6	13	1 19 0
6½	0 17 0	13¼	2 0 0
6¾	0 17 6	13½	2 2 0
7	0 18 0	13¾	2 4 0
7¼	0 18 6	14	2 6 0
7½	0 19 0		

riggers of wood,

		£	s.	d.
above 20 inches diameter, single grooved, and made of 4-inch elm	per foot diam.	0	4	6
double ditto	do.	0	4	0
under 18 inches	do.	0	4	0
double ditto	do.	0	4	0
under 12 inches	do.	0	4	0
iron, covered with wood, for straps or ropes	per foot diam.	0	10	6

ILLWRIGHT's WORK,

Labour prices only,

shafts, of cast iron, collars included, per in. sup.,

	£	s.	d.		£	s.	d.
2 inches....	£0	0	1	5¼ inches....	£0	0	0¾
2¼	0	0	1	5½	0	0	0¾
2½	0	0	1	5¾	0	0	0¾
2¾	0	0	1	6	0	0	0¾
3	0	0	0¾	6¼	0	0	0¾
3¼	0	0	0¾	6½	0	0	0¾
3½	0	0	0¾	6¾	0	0	0¾
3¾	0	0	0¾	7	0	0	0½
4	0	0	0¾	7¼	0	0	0½
4¼	0	0	0¾	7½	0	0	0½
4½	0	0	0¾	7¾	0	0	0½
4¾	0	0	0¾	8	0	0	0½
5	0	0	0¾				

		£	s.	d.
shafts of wood, elm, any size	per foot cube	0	2	0
do. fir	do.	0	1	6
do. oak	do.	0	2	6
staves of beech or hornbeam, turned..	per foot run	0	0	3
wallowers, with staves	per foot diam.	0	15	0
wash wheels, the rings, arms, and sides of elm, &c., 6 feet diameter, and 4 feet wide..	per foot diam.	1	5	0
7 feet ditto ditto ..	do.	1	7	0
wood horse yokes, of 4-inch elm	per pair	0	7	6
water wheel work, elm rings, from 4½ to 5 inches thick, with oak griped arms to ditto,	per ft. diam.	0	10	0
oak rings, from 4½ to 5 inches thick	do.	0	12	6
ditto starts	per foot run	0	0	4
floats and back boards of elm, prepared to size	per foot sup.	0	0	2½
overshot wheels, rings and arms, &c.,	per ft. dia.	0	12	0
sole boards, risers, buckets, &c., to ditto	per foot sup.	0	0	2
wheels, bevel of wood,				
for the bevel charge, in addition......	per foot	0	1	6
windmill breaks, 9 inches wide	per foot diam.	0	9	0
maltmill heads with staves	do.	0	15	0
wallowers, with staves	do.	0	18	0
spur nuts, with ditto	do.	0	16	0

wheels of cast iron, tooth and mortis geared, pitched, chipped, and filed, including pattern :—

width of cog,	pr. ft. diam.			width of cog,	pr. ft. diam.		
2 inches....	£1	0	0	5¼ inches......	1	18	0
2¼	1	1	0	5½	1	18	6
2½	1	2	0	5¾	1	19	0
2¾	1	3	6	6	2	0	0
3	1	5	0	6¼	2	1	0
3¼	1	6	6	6½	2	2	0
3½	1	8	0	6¾	2	3	0
3¾	1	9	0	7	2	4	0
4	1	10	0	7¼	2	5	0
4¼	1	11	6	7½	2	6	6
4½	1	13	0	7¾	2	8	0
4¾	1	15	0	8	2	10	0
5	1	17	6	8¼	2	12	0

Steam is also of great utility as a productive source of motive power; and in this respect its properties are *elastic force*, *expansive force*, and *reduction by condensation*. Elastic force signifies the whole urgency or power the steam is capable of exerting with undiminished effect. By expansive force is generally understood the amount of diminishing effect of the steam on the piston of a steam engine, reckoning from that point of the stroke where the steam of uniform elastic force is cut off; but it is more properly the force which steam is capable of exerting when expanded to a known number of times its original bulk. And

Condensation, here understood, is the abstraction or reduction of heat by another body, and consequently not properly a contained property of the steam, but an effect produced by combined agency, in which steam is the principal; because any colder body will extract the heat and produce condensation, but steam cannot be so beneficially replaced by any other fluid capable of maintaining equal results.

The rules formed by experimenters as corresponding with the results of their experiments on the elastic force of steam at given temperatures vary, but approximate so closely that the following rule, because of being simple, may in practice be taken in preference to any other.

Rule.—To the temperature of the steam in degrees of Fahrenheit, add 100, divide the sum by 177, and the 6th power of the quotient equal the force in inches of mercury.

Ex. Required the force of steam corresponding to a temperature of 312°.

$$\frac{312+100}{177}=2{\cdot}3277^6=159 \text{ inches of mercury.}$$

PARALLEL MOTIONS.

Plate
B

Fig. 1.

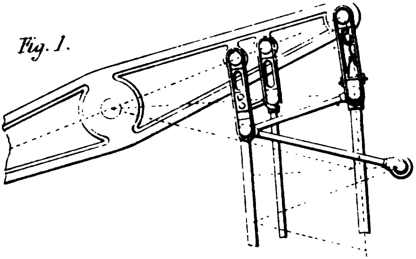


Fig. 2.

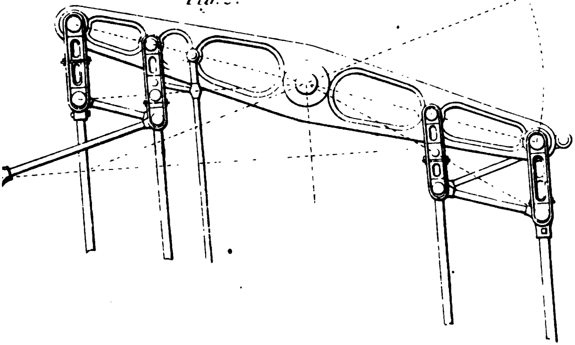
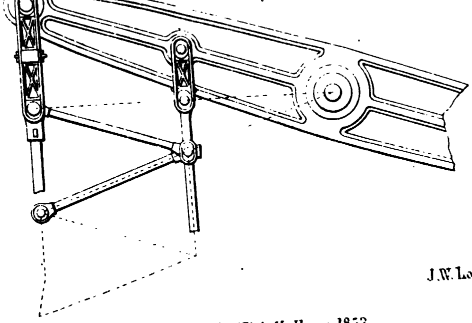


Fig. 3.



J.W. Lowry sc

John Weale, 59, High Holborn 1853.

PARALLEL MOTIONS.

Plate
F

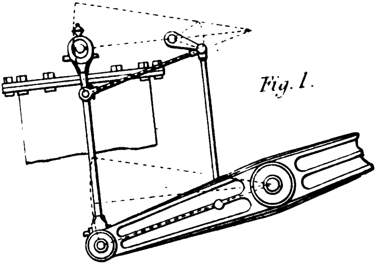


Fig. 1.

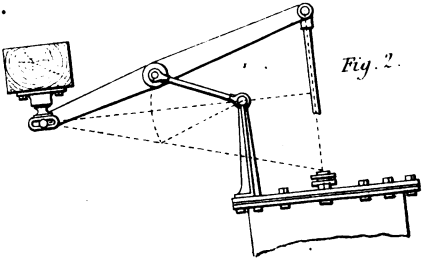
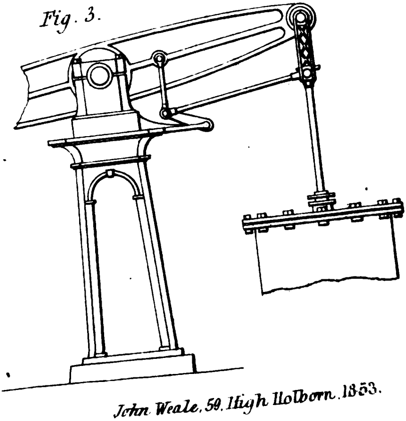


Fig. 2.

Fig. 3.


John Weale, 59, High Holborn. 1853.

ut the Table, page 257, is much better adapted ractical purposes, as the various results or effects btained simply by inspection.

o estimate the amount of advantage gained by g steam expansively in a steam engine.

hen steam of a uniform elastic force is employed ughout the whole ascent or descent of the piston, mount of effect produced is as the quantity of n expended. But let the steam be shut off at portion of the stroke, say, for instance, at one it expands by degrees until the termination of stroke, and then exerts half its original force; e an accumulation of effect in proportion to the tity of steam.

ule.—Divide the length of the stroke by the dis- e or space into which the dense steam is admitted, find the hyperbolic logarithm of the quotient, to h add 1, and the sum is the ratio of the gain.

x. Suppose an engine with a stroke of 6 feet, and steam cut off when the piston has moved through required the ratio of gain by uniform and expan- force.

÷2=3; hyperbolic logarithm of 3=1·0986+1=2·0986 ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at ⅓=2·0986.

gain, let the greatest elastic force of steam in the nder of an engine equal 48lbs. per square inch, let it be cut off from entering the cylinder when piston has moved 4½ inches, the whole stroke g 18; required an equivalent force of the steam ughout the whole stroke.

18÷4·5=4, and 48÷4=12.
Logarithm of 4+1=2·38629.
Then 2·38629×12=28·635 lbs. per square inch.

Table of Hyperbolic Logarithms.

No.	Logrthm.	No.	Logrthm.	No.	Logrthm.	No.	Logrthm.
1¼	·22314	3½	1·25276	5¾	1·74919	8	2·07944
1½	·40546	3¾	1·32175	6	1·79175	8½	2·14006
1¾	·55961	4	1·38629	6¼	1·83258	9	2·19722
2	·69314	4¼	1·44691	6½	1·87180	9½	2·25129
2¼	·81093	4½	1·50507	6¾	1·90954	10	2·30258
2½	·91629	4¾	1·55814	7	1·94591	12	2·48490
2¾	1·01160	5	1·60943	7¼	1·98100	14	2·63905
3	1·09861	5¼	1·65822	7½	2·01490	16	2·77258
3¼	1·17865	5½	1·70474	7¾	2·04769	18	2·89037

In regard to the other case of expansion: Wh the temperature is constant the bulk is inversely as t pressure: thus, Suppose steam at 30 lbs. per squa inch, required its bulk to that of original bulk, wh expanded so as to retain a pressure equal to that the atmosphere, or 15 lbs.

$$\frac{15+30}{15}=3 \text{ times its original bulk,}$$

Condensation of steam for motive purposes, gen rally, is effected by cold water, the quantity of whi may be estimated by the following rule. From 10 plus the temperature of the steam, subtract the quired temperature of the condensed water, divide t remainder by the temperature of the condensed wat minus the temperature of the cold or condensi water, and the quotient equal the number of tim that the quantity, for condensation, must exceed t by which the steam is formed.

Ex. Required the ratio or quantity of water condensation to 1 of water for the formation of stea the temperature of the steam being 220°, and the quired temperature of condensed water 180°.

$$\frac{1000+220-180}{180-52}=8 \text{ times the quantity.}$$

· holding impurities in solution tends to retard ing the aëriform state, and so impairs the of its elastic force at an equal temperature, as l in the following Tables. Thus, common ils at 212° Fahrenheit.

of Substance.		Proportionate quantity in 100 parts by weight of water.	Boiling points.
in sea water.		3·03	213·2° F.
e of soda	In common water.	31·5	213
e of iron		64	216
....		52	220
e of lime		45	220
e of magnesia ...		57·5	222
of soda		30	224
of soda............		60	246
of soda............		60	256

tic Force of Steam in Inches of Mercury.

water } boiling point, 212° F. { elastic force 30 in.
. ... } at 212 „ { „ 23·05 „
water } boiling point, 216° F. { elastic force 32·5 in.
r ...... } at 216 „ { „ 24·6 „
water } boiling point, 220° F. { elastic force 35·1 in.
r ...... } at 200 „ { „ 26·5 „

e the propriety of procuring, for steam, water irest state.

ffects produced by air in its natural and also in a rarefied state.

weight or pressure of the atmosphere is equal veight of a column of water 34 feet in height, column of mercury 30 inches in height, or to i. av. per square inch at a mean temperature. *like all other* gases, is rendered lighter by the application of heat, for then the particles of the mass are repelled from each other, or rarefied, and occupy a greater space. Rarefied air being specifically lightest, mounts above that of common density; hence change of temperature, and the principal cause of winds.

Table of the Expansion of Atmospheric Air by Heat.

Degrees of Fahr.	Bulk.	Degrees of Fahr.	Bulk.	Degrees of Fahr.	Bulk.
32°	1000	65°	1077	100°	1152
35	1007	70	1089	120	1194
40	1021	75	1099	140	1235
45	1032	80	1110	160	1275
50	1043	85	1121	180	1315
55	1055	90	1132	200	1364
60	1066	95	1142	212	1376

The pressure or gravity of the atmosphere being equal to a column of water 34 feet in height, is the means or principle on which rests the utility of the common pump, also of the syphon and all other such hydraulic applications. In a pump the internal pressure on the surface of the liquid is removed by the action of the bucket, and as by degrees the density becomes lessened, so the water rises by the external pressure to the above-named height; and at such height it will remain, unless by some derangement of construction taking place, the atmospheric fluid is allowed to enter and displace the liquid column. But observe if the temperature of the water or other liquid be so elevated that steam or vapour arises through it, then, according to the vapour's accumulation of density, may the action of the pump be partially or wholly destroyed; and the only means of evasion in such cases is to place the working bucket beneath the surface of the liquid which is required to be raised.

Table showing the quantity of Water per lineal foot in Pumps or Vertical Pipes of different diameters.

Diameter of pump in inches.	Number of gallons pr. lineal ft.	Number of cubic feet pr. lineal ft.	Diameter of pump in inches.	Number of gallons pr. lineal ft.	Number of cubic feet pr. lineal ft.
2	·136	·0218	8	2·176	·3490
2¼	·172	·0276	8¼	2·314	·3712
2½	·212	·0340	8½	2·456	·3940
2¾	·257	·0412	8¾	2·603	·4175
3	·306	·0490	9	2·754	·4417
3¼	·359	·0576	9¼	2·909	·4666
3½	·416	·0668	9½	3·068	·4923
3¾	·478	·0766	9¾	3·232	·5184
4	·544	·0872	10	3·400	·5454
4¼	·614	·0985	10¼	3·572	·5730
4½	·688	·1104	10½	3·748	·6013
4¾	·767	·1230	10¾	3·929	·6302
5	·850	·1363	11	4·114	·6599
5¼	·937	·1503	11¼	4·303	·6902
5½	1·028	·1649	11½	4·496	·7212
5¾	1·124	·1803	11¾	4·694	·7529
6	1·224	·1963	12	4·896	·7853
6¼	1·328	·2130	12½	5·312	·8521
6½	1·436	·2304	13	5·746	·9217
6¾	1·549	·2489	13½	6·196	·9939
7	1·666	·2672	14	6·664	1·0689
7¼	1·787	·2866	15	7·650	1·2271
7½	1·912	·3067	16	8·704	1·3962
7¾	2·042	·3275	18	11·016	1·7670

Examples illustrative of the Utility of the Table.

1. Required the quantity of water lifted by each stroke of the bucket of a 9½-inch pump, the length of the stroke being 2¼ feet.

3·068 × 2·25=6·903 gallons each stroke.

2. What length of stroke with a 6-inch pump will be *necessary to* discharge 44 gallons of water per

minute, the number of strokes being 18 in the given time?

$$\frac{44}{1{\cdot}224\times18}=2 \text{ feet, the length of stroke.}$$

3. What must be the diameter capable of raising 25 cubic feet of water per minute, the length of the stroke being 2½ feet, and making 16 effective strokes per minute?

$$\frac{25}{2{\cdot}5\times16}={\cdot}625, \text{ or } 10\tfrac{3}{4} \text{ inches nearly.}$$

It is by the oxygen of the atmosphere that combustion is supported. The common combustibles of nature are chiefly compounds of carbon and hydrogen, which, during combustion, combine with the oxygen of the atmosphere, and are converted into carbonic acid and watery vapour, different species of fuel requiring different quantities of oxygen. The quantity required for the combustion of a pound of coal varies from 2 to 3 lbs., according to the quality of the coal: 60 cubic feet of atmospheric air is necessary to produce 1 lb. of oxygen.

The pressure or fluid properties of the atmosphere oppose bodies in passing through it, the opposing resistance increasing as the square of the velocity of the body, and the resistance per square foot in lbs. as its velocity in feet per second, multiplied into ·002288. Thus, suppose a locomotive engine in a still atmosphere, at a velocity of 25 miles per hour, presents a resisting frontage of 20 feet; required the amount of opposing resistance at that velocity.

25 miles per hour equal 36·67 feet per second.

Then $36{\cdot}67^2\times{\cdot}002288\times20=61{\cdot}5$ lbs. constant opposing force.

Table of the force and common Appellations given to Winds at different velocities.

Velocity of the wind in		Force in lbs. avoirdupois per square foot.	Common Appellations given to the Wind.
Miles per hour.	Feet per second.		
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·40	·044	
4	5·87	·079	Gentle pleasant wind
5	7·33	·123	
10	14·67	·492	Pleasant brisk gale.
15	22·00	1·107	
20	29·34	1·968	Very brisk.
25	36·67	3·075	
30	44·01	4·429	High winds.
35	51·34	6·027	
40	58·68	7·873	Very high.
45	66·01	9·963	
50	73·35	12·300	A storm or tempest.
60	88·02	17·715	A great storm.
80	117·36	31·490	A hurricane.

In order to gain the greatest amount of the wind's npulsive effect to produce rotary or circular motion y the sails of a wind-mill, the total surface of the ails presented to the wind ought to be about ⅞ths of he circle's surface which is formed by their motion, nd each sail angled to the plane of motion as follows, he whip or back being divided into six equal parts.

Distance from centre of motion	1	2	3	4	5	6	Smeaton's rule.
Angle with plane of motion...	18°	19	18	16	12½	7	
By *G. Forrester, Liverpool*	24°	21	18	14	9	3	

RULES, TABLES, &c., RELATIVE TO BOILERS AND THE STEAM ENGINE.

THE Boiler of a Steam Engine may be explained as that portion of the structure in which the vital principle of the engine is generated; consequently its construction is of the utmost importance, for upon the proper efficiency of the boiler depends in a great measure the efficiency of the engine.

Boilers not unfrequently, because of unavoidable peculiarities, are necessarily constructed of various forms; but for land or stationary engine boilers, if no thwarting circumstances intervene, either the waggon or cylindrical forms are commonly resorted to; the former for those of condensing engines, and the latter for those of the high pressure principle.

In the construction of boilers, much attention ought to be paid in avoiding thin films of water where the action of the fire is great, because it is neither consistent with safety, nor can there be the proper quantities of steam generated according to the surface exposed, unless under some extraordinary degree of pressure. Also convex surfaces, exposed to the action of the steam, unless properly supported, ought strenuously to be avoided. Large water spaces, concave surfaces, or straight plates securely stayed, with ample steam room, are the chief requisites to be attended to.

1. *To determine the proper quantity of heating surface in a boiler for an engine with a cylinder of a given capacity, and steam at any density required.*

Rule.—Multiply 375 times the area of the cylinder in feet by the velocity of the piston in feet per minute, and divide the product by the volume of steam to 1 of water at the density required (see Table, page 242), and the quotient is the amount of effective heating surface in square feet.

Ex. Required the amount of effective heating surface in a boiler for an engine whose cylinder is 4½ square feet in area, and the piston's velocity 224 feet per minute, the pressure of the steam to equal 5 ℔s. per square inch above the pressure of the atmosphere.

$\frac{375 \times 4{\cdot}5 \times 224}{1282} = 295$ square feet nearly; the fire-grate being in accordance with the following rule.

Multiply the number of square feet of heating surface by ·12, the product equal the area of fire-grate in square feet, thus :

$295 \times {\cdot}12 = 35{\cdot}4$ square feet of furnace-bar.

Note.—By effective heating surface is meant horizontal surfaces over fire, flame, or heated air; vertical or side surfaces requiring about 1¾ ft. to equal in effect 1 of horizontal surface.

2. *To determine the proper dimensions for a waggon-shaped boiler, when the amount of effective heating surface in square feet is obtained by the preceding rule.*

1. The bottom surface equal half the whole surface.
2. The length of the boiler equal twice the square root of bottom surface.
3. The width equal one-fourth the length; and
4. The height equal one-third the length.

Ex. Required the dimensions for a boiler of the waggon form that may present an effective heating surface of 295 square feet.

Bottom surface $= 295 \div 2$, or $147{\cdot}5$ square feet.
Length . . . $= \sqrt{147{\cdot}5} \times 2$, or $24{\cdot}26$ feet.
Width . . . $= 24{\cdot}26 \div 4$, or $6{\cdot}06$ feet.
Height . . . $= 24{\cdot}26 \div 3$, or $8{\cdot}08$ feet.

Note.—The amount of side or vertical surface equal twice the length of the boiler, added to the width, and multiplied by 1·75 to obtain that of effective surface; hence,

$$\frac{147{\cdot}5 \times 1{\cdot}75}{24{\cdot}26 \times 2 + 6{\cdot}06} = 4{\cdot}7 \text{ feet, depth of side flue.}$$

3. *To determine the dimensions for a cylindrical boiler.*

Rule.—Extract the square root of 1·34 times the effective heating surface in square feet, and twice the root equal the boiler's circumference in feet; also, the circumference equal the length.

Ex. Let a cylindrical boiler be required with an effective heating surface of 86 square feet; what must be its length and diameter in feet?

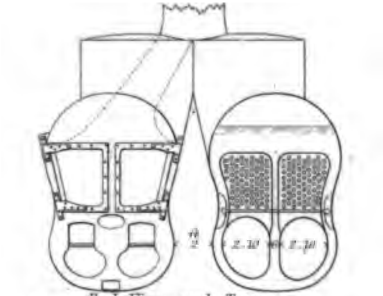
$\sqrt{86 \times 1{\cdot}34} = 10{\cdot}74 \times 2 = 21{\cdot}48$ feet circumference, or 6 feet 10 inches diameter, and 21·48 feet in length.

Note.—When an internal flue is to be inserted in a boiler, the external surface of the boiler may be diminished in length equal to half the exposed surface of the flue. Observe, also, that the height of the contained water in boilers generally ought to be about ⅔rds the whole height of the boiler.

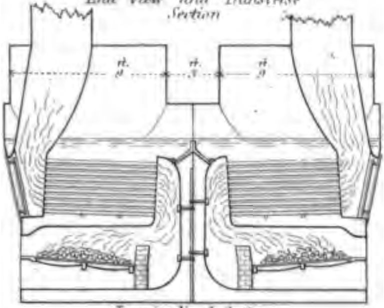
Marine Engine Boilers have become so varied in their designs, that any attempt at enumerating—by ever so slight a description—those that may be considered worthy of record, would much exceed the limits of my present purpose; but having been favoured by Messrs. Bury, Curtis, and Kennedy, with particulars of the boilers constructed by them for the 'Braganza' steam vessel, and which have given the highest degree of satisfaction in every respect, I annex designs and data, in preference to those of any other description. (See Plate K.)

These boilers are constructed so as to work at 10 lbs. per square inch if required; they are four in number; the diameter of each cylinder is 62⅛ inches, length of stroke 5½ feet, or calculated velocity *about 231* feet per minute: the nominal power of each

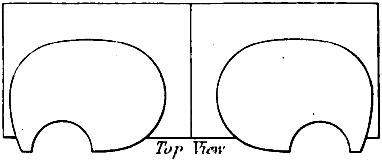
Plate K



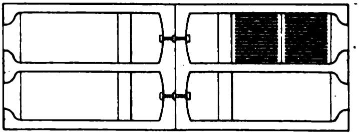
End View and Transverse Section



Longitudinal Section



Top View



Ground Plan

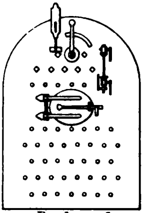
Plans of the Boilers on board the Peninsular Co.s Steam Ship Braganza.
By Messrs Bury, Curtis and Kennedy, Liverpool.

W. T. del.

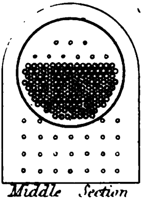
G. Gladwin, sc.

London: J. Weale, 1853.

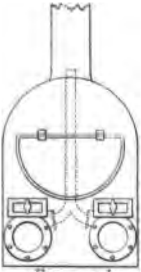
Plate 1



Back end

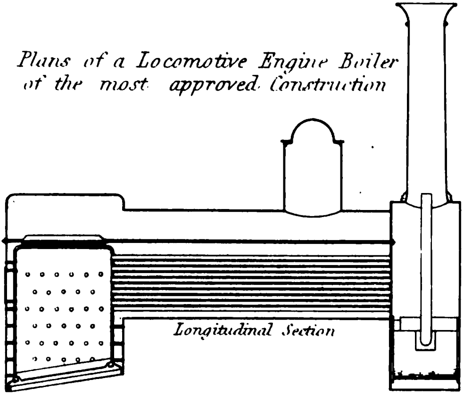


Middle Section

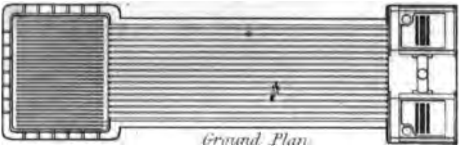


Fore end

Plans of a Locomotive Engine Boiler of the most approved Construction



Longitudinal Section



Ground Plan

W. T., del. G. Gladwin, sc.

London: J. Weale, 1853.

engine is 140 horses, and the heating surface per horse-power is 14·1 square feet.

Now 14·1 × 140 = 1974 square feet to each engine.

Then as per rule (page 268), 375 multiplied by the area of cylinder or 21 feet, and by the velocity per minute or 231 feet, and divided by 1044 (see Table, page 258) or volume of steam to 1 of water, at 10lbs. per square inch, equal 1742·4 square feet; to which add about ⅛th of the quotient, or 217·8, for side or vertical surface, equal 1960·2 square feet to each engine,—thus nearly corresponding with *their* given quantity of heating surface.

Note.—In the four boilers there are 608 brass tubes, 6¼ feet in length and 3 inches in diameter. The length of each fireplace is 5 feet 10 inches, and breadth 2 feet 10; there are, ·56 of a square foot of fire-bar to each cubic foot of cylinder capacity, and ·16 of a square foot of tube aperture to each square foot of fire-bar, the openings of the tubes being reduced by the thickness of the tube hoops. The diameter of each chimney, of which there are two, is 3 feet 5 inches.

Locomotive Boilers, in the manner of their construction, are a class which, of necessity, demand the utmost degree of qualified attention, because of the great pressures they are required to sustain, and the unavoidably narrow limits in which such vast volumes of steam are required to be generated.

In boilers of this description, it is of the most essential consequence that the water spaces in the fire-box be of a sufficient width, say, on the back and sides, not less than 2¾ to 3 inches, and in the front, where the tendency of the fire is urged by the action of the blast-pipe, at least 3½ inches.

The boiler which I have selected for illustration (see Plate L) is of the most modern description; and from an intimate knowledge of its performances, I am enabled to assert, with full confidence, that it *possesses* efficient and economical properties to the *production* of steam.

Specified particulars relative to the Boiler and Engine.

Diameter of cylinders	14 inches.
Length of stroke	18 „
Lap of the valve	1 „
Diameter of driving wheels	5½ feet.
Length of internal fire-box	2 feet 11½ inches.
Width of ditto	3 „ 5 „
Length of cylindrical part of boiler	8 „ 8 „
Diameter of ditto	3 „ 4½ „
Length of tubes	8 „ 11½ „
Number of tubes	133, of brass.
Interior diameter of ditto	1¾ inches.
Diameter of blast-pipe	4 „

About 112 lbs. of coke consumed in this boiler evaporate 84 gallons of water; and from 20 to 25 lbs. of coke are consumed per mile.

Heating Powers of Combustible Substances.

Species of combustible	lbs. of water heated from 32° to 212°.	lbs. of boiling water evaporated by 1 lb. of fuel.	lbs. of atmospheric air to each lb. of fuel.
Wood in its ordinary state	26	4·72	4·47
Wood charcoal	73	13·37	11·46
Coal	60	10·90	9·26
Coke	65	11·81	11·46
Turf	30	5·45	4·60
Turf charcoal	64	11·63	9·86

In regard to the giving of an order for a steam engine of any required number of horses' power, it has been argued and ultimately decided, that in a commercial point of view the order is not sufficiently completed by the dimensions of cylinder, boiler, &c. being of ample magnitude to produce the specified dynamical effect in horses' power; and not unless corresponding with the established custom by Boulton and Watt, or that of other manufacturers of equally well known respectability: hence, generally, the foling Tables may be better adapted to practice than n the most simple rule.

ble of Dimensions for Steam Engine Cylinders by celebrated makers.

ationary Con- sing Engines, oulton & Watt.		Marine Engines, by Maudslay, Napier, &c.			High-Pressure, or Non-Condensing Engines, by various makers.				
Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameters of cylinders, the force of the steam being, per square inch, 25 lbs.	30 lbs.	40 lbs.	50 lbs.
14½	3	10	20	2	1	3¾	3½	3	2¾
16¼	3	15	24	2¼	2	5¼	4¾	4¼	3¾
18	3½	20	27	2½	3	6½	6	5	4½
19½	4	25	29½	2¾	4	7½	6¾	6	5¼
21	4½	30	32	3	5	8¼	7½	6½	5⅞
22½	4½	40	36	3½	6	9	8¼	7¼	6½
23½	5	50	40	4	7	9¾	9	7¾	6⅞
24½	5	60	43	4	8	10½	9¾	8½	7½
26	5	70	46½	4½	9	11⅛	10¼	8¾	7⅞
27	5½	80	47½	4½	10	11¾	11	9½	8½
27½	5½	90	50	4¾	11	12¼	11⅜	9¾	8¾
28	5¾	100	53	5	12	13	12	10½	9¼
29	6	110	55½	5½	14	14	12¾	11¼	10
30	6	120	57	5½	16	15	13¾	12	10½
32½	6½	130	60¾	5¾	18	15¾	14½	12¾	11¼
34½	6½	150	65	6	20	16¾	15¼	13½	11¾
38½	7	200	74½	6	25	18½	17¼	15	13¼
42¼	7	250	84	6	30	20¼	19¾	16¼	14½

The *unit* of nominal power for steam engines, or usual estimate of dynamical effect per minute of orse, called by engineers a horse-power, is 000 lbs. at a velocity of 1 foot per minute; or, effect of a load of 200 lbs. raised by a horse for ours a day, at the rate of 2½ miles per hour, or *lbs. at the* rate of 220 feet per minute.

To estimate by means of an indicator the amount of effective power produced by a steam engine.

Rule.—Multiply the area of the piston in square inches by the average force of the steam in lbs. and by the velocity of the piston in feet per minute; divide the product by 33,000, and $\frac{7}{10}$ths of the quotient equal the effective power.

Ex. Suppose an engine with a cylinder of 37½ inches diameter, a stroke of 7 feet, and making 17 revolutions per minute, or 238 feet velocity, and the average indicated pressure of the steam 16·73 lbs. per square inch; required the effective power.

$$\frac{\text{Area}=1104{\cdot}4687\text{ inches}\times16{\cdot}73\text{ lbs}\times238\text{ feet}}{33000}$$

$$=\frac{133{\cdot}26\times7}{10}=93{\cdot}282\text{ horses' power.}$$

To determine the proper velocity for the piston of a steam engine.

Rule.—Multiply the logarithm of the *n*th part of the stroke at which the steam is cut off by 2·3, and to the product of which add ·7. Multiply the sum by the distance in feet the piston has travelled when the steam is cut off, and 120 times the square root of the product equal the proper velocity for the piston in feet per minute.

Ex. Let the steam be cut off in an 8-feet stroke when the piston has travelled ¼th of the length; required its proper velocity.

$$\begin{array}{lr}
\text{Logarithm of } 4= & 0{\cdot}60206 \\
\text{Multiplied by} & 2{\cdot}3 \\ \hline
 & 1{\cdot}384738 \\
\text{To which add} & {\cdot}7 \\ \hline
 & 2{\cdot}084738 \\
 & 2 \\ \hline
\end{array}$$

$$\sqrt{4{\cdot}169476}=2{\cdot}04\times120=245\text{ feet, velocity per minute.}$$

Table of Approximate Velocities for the Pistons of Steam Engines.

CONDENSING ENGINES.			NON-CONDENSING ENGINES.		
Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per minute.	Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per minute.
2	160	40	1½	186	62
2½	177½	35½	2	200	50
3	192	32	2½	212½	42½
3½	203	29	2¾	217¼	39½
4	214	26¾	3	222	37
4½	220½	24½	3½	231	33
5	230	23	4	236	29½
5½	236½	21½	4½	243	27
6	240	20	5	247½	24¾
7	245	17½	5½	253	23
8	256	16	6	264	22

Of the Parallel Motion in a Steam Engine.

When the power from the piston is communicated by means of a beam or lever moving upon an axis, the parallel motion becomes a very important portion of the machine, for then it forms the link of connection, and by its properties renders the action of alternate circular motion and reciprocating vertical motion mutually agreeable, thereby properly insuring to the piston-rod a truly direct line to that of the cylinder: but to effect this, the greatest degree of exactitude of the various parts is required, otherwise extra friction is created, and the effective power of the engine proportionately diminished. (See Plates E. and F.)

Fig. 1, Plate E, is a motion for a double-cylinder engine.
,, 2, ,, a motion for a pumping engine.
,, 3, ,, the common condensing engine.
Fig. 1, Plate F, is for a marine engine.
,, 2, ,, also for a marine engine.
,, *3*, ,, *for a non-condensing or high-pressure engine.*

Table by which to determine the various Distances of the Moveable Points in a Parallel Motion.

Radius of beams in ft.	Parallel bars in ft.	Length of radius rods in ft. & in.	
4 feet	2	2	0
	2¼	1	4⅜
	2½	0	10⅞
	2¾	0	6⅞
	3	0	4
4½ feet	2	3	1½
	2¼	2	3
	2½	1	7¼
	2¾	1	1⅜
	3	0	9
	3¼	0	5¾
5 feet	2	4	6
	2¼	3	4⅜
	2½	2	6
	2¾	1	10⅛
	3	1	4
	3¼	0	11¼
	3½	0	7¾
5½ feet	2¼	4	8⅜
	2½	3	7¼
	2¾	2	9
	3	2	1
	3¼	1	6⅜
	3½	1	1¾
	3¾	0	9⅞
6 feet	2¾	3	10
	3	3	0
	3¼	2	3⅞
	3½	1	9½
	3¾	1	4¼
	4	1	0
	4¼	0	8½
6½ feet	3	4	1⅛
	3¼	3	3
	3½	2	6⅞
	3¾	2	0¼
	4	1	6¾
	4¼	1	2¼
	4½	0	10½
7 feet	3	5	4
	3¼	4	4
	3½	3	6
	3¾	3	2⅞
	4	2	3
	4¼	1	9
	4½	1	4⅝
	4¾	1	0⅞
	5	0	9⅝
7½ feet	3½	4	6⅞
	3¾	3	9
	4	3	0¾
	4¼	2	6
	4½	2	0
	4¾	1	7
	5	1	3
	5¼	0	11½
8 feet	3½	5	9½
	3¾	4	9¾
	4	4	0
	4¼	3	3¾
	4½	2	8⅝
	4¾	2	2¾
	5	1	9⅝
	5¼	1	5¼
8½ feet	3¾	6	0¼
	4	5	6¾
	4¼	4	3
	4½	3	6⅝
	4¾	2	11½
	5	2	5⅜
	5¼	2	0⅛
	5½	1	7⅝
9 feet	4	6	3
	4¼	5	3¾
	4½	4	6
	4¾	3	9⅝
	5	3	2½
	5¼	2	8⅛
	5½	2	2¾
	5¾	1	10
	6	1	6
9½ feet	4½	5	6⅝
	4¾	4	9
	5	4	0⅝
	5¼	3	5⅜
	5½	2	10⅞
	5¾	2	5¼
	6	2	0⅛
10 feet	4¾	5	9½
	5	5	0
	5¼	4	3½
	5½	3	8⅛
	5¾	3	1¾
	6	2	8
	6¼	2	3
	6½	1	10⅛
10½ feet	5	6	0½
	5¼	5	3
	5½	4	6½
	5¾	3	11
	6	3	3¼
	6¼	2	10¾
	6½	2	5⅜
	6¾	2	1
11 feet	5¼	6	3½
	5½	5	6
	5¾	4	9½
	6	4	2
	6¼	3	7⅜
	6½	3	1⅜
	6¾	2	8⅛
11½ feet	5½	6	6½
	5¾	5	9
	6	5	0½
	6¼	4	5
	6½	3	10⅛
	6¾	3	4
	7	2	10⅝
	7¼	2	6
12 feet	5¾	6	8¼
	6	6	0
	6¼	5	3½
	6½	4	7⅞
	6¾	4	1
	7	3	6⅞
	7¼	3	1⅜
	7½	2	8½
	7¾	2	4

LOGARITHMS.

LOGARITHMS literally signify *ratios of numbers;* hence Logarithmic Tables may be various, but those in common use for the facilitating of arithmetical operations generally are of the following corresponding progressions, viz.

Arithmetical,	0,	1,	2,	3,	&c.,	or series of logarithms.
Geometrical,	1,	10,	100,	1000,	&c.,	or ratio of numbers.

And thus it may be perceived, that if the log. of 10 be 1, the log. of any number less than 10 must consist wholly of decimals, because increasing by a decimal ratio. Again, if the log. of 100 be 2, the log. of any intermediate number between 10 and 100 must be 1, with so many decimals annexed; and in like manner, the log. of any intermediate number between 100 and 1000 must be 2, with decimals annexed proportionally, as before.

APPLICATION AND UTILITY OF COMMON LOGARITHMIC TABLES.

The whole numbers of the series of logarithms, as 1, 2, 3, &c., are called the indices, or characteristics of the logarithm, and which must be added to the logarithm obtained by the Table, in proportion to the number of figures contained in the given sum. Thus, suppose the logarithm be required for a sum of only two figures, the index is 1; if of three figures, the index is 2; and if of four figures, the index is 3, &c., being always a number less by unity than the number of figures the given sum contains.

Ex. The index of 8 is 0, because it is less than 10.
The index of 80 is 1, because it is less than 100.
The index of 800 is 2, because it is less than 1000.
The index of 8000 is 3, because it is less than 10,000, &c.

The index of a decimal is always the number which denotes the significant figure from the decimal point, and is marked with the sign thus —, to distinguish it from a whole number.

Ex. The index of ·32549 is —1, because the first significant figure is the first decimal.

The index of ·032549 is —2, because the first significant figure is the second decimal.

The index of ·0032549 is —3, because the first significant figure is the third decimal, and so on, of any other sum.

If the given sum for which the logarithm is required contains or consists of both integers and decimals, the index is determined by the integer part, without having any regard to the other.

1. *To find the logarithm of any whole number under* 100.

Look for the number under N in the first page of any Logarithmic Table; then immediately on the right of it is the logarithm required, with its proper index. Thus, the log. of 64 is 1·806180, and the log. of 72 is 1·857332.

2. *To find the logarithm of any number between* 100 *and* 1000, *or any sum not exceeding* 4 *figures.*

Find the first three figures in the left-hand column of the page under N, in which the number is situated, and the fourth figure, at the top or bottom of the page; then the logarithm directly under the fourth figure, and in a line with the three figures in the column on the left, with its proper index, is the logarithm required. Thus, the log. of 450 is 2·653213, and the log. of 7464 is 3·872972. Or, the log. of 378·5 is 2·578066, and that of ·7854 is —1·895091.

3. *To find the number indicated by a given logarithm.*

Look for the decimal part of the given logarithm in the different columns, and if it cannot be found exactly, take the next less. Then under N in the left-hand column, and in a line with the logarithm found, are three figures of the number required, and on the top of the column in which the found logarithm stands is one figure more; place the decimal point as indicated by the logarithmic index, which determines the sum, properly valued, as required.

If the logarithm cannot be found exactly in the Tables, subtract from it the next less that can be found, and divide the remainder by the tabular difference; the quotient will be the rest of the figures of the given number, which, being annexed to the tabular number already found, is the proper number required.

Ex. Required the number answering to the logarithm 3·233568.

Given logarithm ....=3·233568
Next less is the log. of 1712 ...=3·233504
Remainder 64

Tab. Diff.=253, and $\frac{64}{253}$=·25

Hence the number required=1712·25.

For practical purposes in mechanics, logarithms are seldom resorted to, unless for the raising of the powers of numbers or extraction of their roots; these operations, when Tables are at hand, they very much facilitate; involution, or the raising of powers, being performed simply by multiplication; and evolution, or the extraction of roots, by division, as in simple arithmetic.

Ex. 1. Required the square or second power of 25·791.

Log. of 25·791 $=1·411468$
Multiplied by $\underline{\quad\quad 2}$, the power required.
Logarithm 2·822936, indicated number or square required$=$665·175.

Ex. 2. What is the cube of 30·7146?

Logarithm $=1·487345$
Multiplied by $\underline{\quad\quad 3}$, the power required.
Logarithm 4·462035, indicated number or cube required$=$28975·7.

Ex. 3. Required the square root of 365.

Log.$=\frac{2·562293}{2}=1·281146$, indicated number or root$=$ 19·105.

Ex. 4. Find the cube root of 12345.

Log.$=\frac{4·091491}{3}=1·363830$, indicated number or root$=$ 23·1116.

Table of Logarithms from 1 *to* 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0·000000	26	1·414973	51	1·707570	76	1·880814
2	0·301030	27	1·431364	52	1·716003	77	1·886491
3	0·477121	28	1·447158	53	1·724276	78	1·892095
4	0·602060	29	1·462398	54	1·732394	79	1·897627
5	0·698970	30	1·477121	55	1·740363	80	1·903090
6	0·778151	31	1·491362	56	1·748188	81	1·908485
7	0·845098	32	1·505150	57	1·755875	82	1·913814
8	0·903090	33	1·518514	58	1·763428	83	1·919078
9	0·954243	34	1·531479	59	1·770852	84	1·924279
0	1·000000	35	1·544068	60	1·778151	85	1·929419
1	1·041393	36	1·556303	61	1·785330	86	1·934498
2	1·079181	37	1·568202	62	1·792392	87	1·939519
3	1·113943	38	1·579784	63	1·799341	88	1·944483
4	1·146128	39	1·591065	64	1·806180	89	1·949390
5	1·176091	40	1·602060	65	1·812913	90	1·954243
6	1·204120	41	1·612784	66	1·819544	91	1·959041
7	1·230449	42	1·623249	67	1·826075	92	1·963788
8	1·255273	43	1·633468	68	1·832509	93	1·968483
9	1·278754	44	1·643453	69	1·838849	94	1·973128
20	1·301030	45	1·653213	70	1·845098	95	1·977724
21	1·322219	46	1·662758	71	1·851258	96	1·982271
22	1·342423	47	1·672098	72	1·857332	97	1·986772
23	1·361728	48	1·681241	73	1·863323	98	1·991226
24	1·380211	49	1·690196	74	1·869232	99	1·995635
25	1·397940	50	1·698970	75	1·875061	100	2·000000

Note.—The best Tables of Logarithms are those by Taylor, Gardiner, Hutton, Babbage, and Caillet. The smaller works are those by Lalande, Hassler, Renaud, Christison, and Wallace, and those published in the 'Library of Useful Knowledge.'

Tables of the Circumferences of Circles to the nearest fraction of practical measurement; also the Areas of Circles in inches and decimal parts, likewise of feet and decimal parts, as may be required.

Rules that may render the following Tables more generally useful.

1. Any of the areas in inches multiplied by ·04328, or the areas in feet multiplied by 6·232, the product is the number of imperial gallons at 1 foot in depth.

2. Any of the areas in feet multiplied by ·03704, the product equal the number of cubic yards at 1 foot in depth.

3. The area of a circle in inches multiplied by the length or thickness in inches, and by ·263, the product equal the weight in lbs. of cast iron.

Note.—The French cubic metre, or unit of solid measure, equal 35·31716 English cubic feet. Also the litre, or unit for measures of capacity, equal 61·028 English cubic inches, or about ·453 of an imperial gallon.

Dia. in inch.	Circum. in inch.	Area in sq. inch.	Side of = squ.
1/16	·196	·0030	·0554
1/8	·392	·0122	·1107
3/16	·589	·0276	·1661
1/4	·785	·0490	·2115
5/16	·981	·0767	·2669
3/8	1·178	·1104	·3223
7/16	1·374	·1503	·3771
1/2	1·570	·1963	·4331
9/16	1·767	·2485	·4995
5/8	1·963	·3068	·5438
11/16	2·159	·3712	·6093
3/4	2·356	·4417	·6646
13/16	2·552	·5185	·7200
7/8	2·748	·6013	·7754
15/16	2·945	·6903	·8308
1 in.	3 1/8	·7854	7/8
1 1/8	3 1/2	·9940	7/8 & 3/32
1 1/4	3 7/8	1·227	1 in.
1 3/8	4 1/4	1·484	1 3/16
1 1/2	4 5/8	1·767	1 5/16
1 5/8	5 1/8	2·074	1 7/16
1 3/4	5 1/2	2·405	1 9/16
1 7/8	5 7/8	2·761	1 11/16
2 in.	6 1/4	3·141	1 3/4
2 1/8	6 5/8	3·546	1 7/8
2 1/4	7	3·976	2 in.
2 3/8	7 3/8	4·430	2 1/8
2 1/2	7 3/4	4·908	2 3/16
2 5/8	8 1/4	5·412	2 5/16
2 3/4	8 5/8	5·939	2 7/16
2 7/8	9	6·491	2 9/16
3 in.	9 3/8	7·068	2 5/8
3 1/8	9 3/4	7·669	2 3/4
3 1/4	10 1/4	8·295	2 7/8
3 3/8	10 5/8	8·946	3 in.
3 1/2	11	9·621	3 1/8
3 5/8	11 3/8	10·320	3 1/4
3 3/4	11 3/4	11·044	3 3/8
3 7/8	12 1/8	11·793	3 7/16

Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
4 in.	1	0½	12·566	·0879	9. in.	2	4¼	63·617	·4453
4⅛	1	0⅞	13·364	·0935	9⅛	2	4⅝	65·396	·4577
4¼	1	1⅜	14·186	·0993	9¼	2	5	67·200	·4704
4⅜	1	1¾	15·033	·1052	9⅜	2	5⅜	69·029	·4832
4½	1	2⅛	15·904	·1113	9½	2	5¾	70·882	·4961
4⅝	1	2½	16·800	·1176	9⅝	2	6¼	72·759	·5093
4¾	1	2⅞	17·720	·1240	9¾	2	6⅝	74·662	·5226
4⅞	1	3¼	18·665	·1306	9⅞	2	7	76·588	·5361
5 in.	1	3⅝	19·635	·1374	10 in.	2	7⅜	78·540	·5497
5⅛	1	4⅛	20·629	·1444	10⅛	2	7¾	80·515	·5636
5¼	1	4½	21·647	·1515	10¼	2	8⅛	82·516	·5776
5⅜	1	4⅞	22·690	·1588	10⅜	2	8½	84·540	·5917
5½	1	5¼	23·758	·1663	10½	2	8⅞	86·590	·6061
5⅝	1	5⅝	24·850	·1739	10⅝	2	9⅜	88·664	·6206
5¾	1	6	25·967	·1817	10¾	2	9¾	90·762	·6353
5⅞	1	6⅜	27·108	·1897	10⅞	2	10⅛	92·855	·6499
6 in.	1	6¾	28·274	·1979	11 in.	2	10½	95·033	·6652
6⅛	1	7¼	29·464	·2062	11⅛	2	10⅞	97·205	·6804
6¼	1	7⅝	30·679	·2147	11¼	2	11¼	99·402	·6958
6⅜	1	8	31·919	·2234	11⅜	2	11¾	101·623	·7143
6½	1	8⅜	33·183	·2322	11½	3	0⅛	103·869	·7270
6⅝	1	8¾	34·471	·2412	11⅝	3	0½	106·139	·7429
6¾	1	9¼	35·784	·2504	11¾	3	0⅞	108·434	·7590
6⅞	1	9½	37·122	·2598	11⅞	3	1¼	110·753	·7752
7 in.	1	10	38·484	·2693	12 in.	3	1⅝	113·097	·7916
7⅛	1	10⅜	39·871	·2791	12⅛	3	2	115·466	·8082
7¼	1	10¾	41·282	·2889	12¼	3	2½	117·859	·8250
7⅜	1	11⅛	42·718	·2990	12⅜	3	2⅞	120·276	·8419
7½	1	11½	44·178	·3092	12½	3	3¼	122·718	·8590
7⅝	1	11⅞	45·663	·3196	12⅝	3	3⅝	125·185	·8762
7¾	2	0⅜	47·173	·3299	12¾	3	4	127·676	·8937
7⅞	2	0¾	48·707	·3409	12⅞	3	4⅜	130·192	·9113
8 in.	2	1⅛	50·265	·3518	13 in.	3	4¾	132·732	·9291
8⅛	2	1½	51·848	·3629	13⅛	3	5¼	135·297	·9470
8¼	2	1⅞	53·456	·3741	13¼	3	5⅝	137·886	·9642
8⅜	2	2¼	55·088	·3856	13⅜	3	6	140·500	·9835
8½	2	2⅝	56·745	·3972	13½	3	6⅜	143·139	1·0019
8⅝	2	3	58·426	·4089	13⅝	3	6¾	145·802	1·0206
8¾	2	3⅜	60·132	·4209	13¾	3	7⅛	148·489	1·0294
8⅞	2	3⅞	61·862	·4330	13⅞	3	7½	151·201	1·0584

Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
14	3	7⅞	153·938	1·0775	19	4	11⅝	283·529	1·9847
14⅛	3	8⅜	156·699	1·0968	19⅛	5	0	287·272	1·9941
14¼	3	8¾	159·485	1·1193	19¼	5	0½	291·039	2·0371
14⅜	3	9⅛	162·295	1·1360	19⅜	5	0⅞	294·831	2·0637
14½	3	9½	165·130	1·1569	19½	5	1¼	298·648	2·0904
14⅝	3	9⅞	167·989	1·1749	19⅝	5	1⅝	302·489	2·1172
14¾	3	10¼	170·873	1·1961	19¾	5	2	306·355	2·1443
14⅞	3	10¾	173·782	1·2164	19⅞	5	2⅜	310·245	2·1716
15	3	11⅛	176·715	1·2370	20	5	2⅞	314·160	2·1990
15⅛	3	11½	179·672	1·2577	20⅛	5	3¼	318·099	2·2265
15¼	3	11⅞	182·654	1·2785	20¼	5	3⅝	322·063	2·2543
15⅜	4	0¼	185·661	1·2996	20⅜	5	4	326·051	2·2822
15½	4	0⅝	188·692	1·3208	20½	5	4⅜	330·064	2·3103
15⅝	4	1	191·748	1·3422	20⅝	5	4¾	334·101	2·3386
15¾	4	1½	194·828	1·3637	20¾	5	5⅛	338·163	2·3670
15⅞	4	1⅞	197·933	1·3855	20⅞	5	5½	342·250	2·3956
16	4	2¼	201·062	1·4074	21	5	5⅞	346·361	2·4244
16⅛	4	2⅝	204·216	1·4295	21⅛	5	6⅜	350·497	2·4533
16¼	4	3	207·394	1·4517	21¼	5	6¾	354·657	2·4824
16⅜	4	3⅜	210·597	1·4741	21⅜	5	7⅛	358·841	2·5117
16½	4	3¾	213·825	1·4967	21½	5	7½	363·051	2·5412
16⅝	4	4¼	217·077	1·5195	21⅝	5	7⅞	367·284	2·5708
16¾	4	4⅝	220·353	1·5424	21¾	5	8¼	371·543	2·6007
16⅞	4	5	223·654	1·5655	21⅞	5	8¾	375·826	2·6306
17	4	5⅜	226·980	1·5888	22	5	9⅛	380·133	2·6608
17⅛	4	5¾	230·330	1·6123	22⅛	5	9½	384·465	2·6691
17¼	4	6⅛	233·705	1·6359	22¼	5	9⅞	388·822	2·7016
17⅜	4	6½	237·104	1·6597	22⅜	5	10¼	393·203	2·7224
17½	4	6⅞	240·528	1·6836	22½	5	10⅝	397·608	2·7632
17⅝	4	7⅜	243·977	1·7078	22⅝	5	11	402·038	2·7980
17¾	4	7¾	247·450	1·7321	22¾	5	11½	406·493	2·8054
17⅞	4	8⅛	250·947	1·7566	22⅞	5	11⅞	410·972	2·8658
18	4	8½	254·469	1·7812	23	6	0¼	415·476	2·8903
18⅛	4	8⅞	258·016	1·8061	23⅛	6	0⅝	420·004	2·9100
18¼	4	9¼	261·587	1·8311	23¼	6	1	424·557	2·9518
18⅜	4	9¾	265·182	1·8562	23⅜	6	1⅜	429·135	2·9937
18½	4	10⅛	268·803	1·8816	23½	6	1¾	433·737	3·0129
18⅝	4	10½	272·447	1·9071	23⅝	6	2¼	438·363	3·0261
18¾	4	10⅞	276·117	1·9328	23¾	6	2⅝	443·014	3·072
18⅞	4	11¼	279·811	1·9586	23⅞	6	3	447·690	3·10

in	Circum. in		Area in	Area in	Dia. in		Circum.in		Area in	Area in
in.	ft.	in.	sq. inch.	sq. feet.	ft.	in.	ft.	in.	sq. inch.	sq. feet.
0	6	3⅜	452·390	3·1418	2	10	8	10¾	907·922	6·3051
0¼	6	4⅛	461·864	3·2075	2	10¼	8	11½	921·323	6·3981
0½	6	4⅞	471·436	3·2731	2	10½	9	0⅜	934·822	6·4911
0¾	6	5¾	481·106	3·3410	2	10¾	9	1⅛	948·419	6·5863
1	6	6½	490·875	3·4081	2	11	9	1⅞	962·115	6·6815
1¼	6	7¼	500·741	3·4775	2	11¼	9	2¾	975·908	6·7772
1½	6	8⅛	510·706	3·5468	2	11½	9	3½	989·800	6·8738
1¾	6	8⅞	520·769	3·6101	2	11¾	9	4¼	1003·79	6·9701
2	6	9⅝	530·930	3·6870	3	0	9	5	1017·87	7·0688
2¼	6	10½	541·189	3·7583	3	0¼	9	5⅞	1032·06	7·1671
2½	6	11¼	551·547	3·8302	3	0½	9	6⅝	1046·35	7·2664
2¾	7	0	562·002	3·9042	3	0¾	9	7½	1060·73	7·3662
3	7	0¾	572·556	3·9761	3	1	9	8¼	1075·21	7·4661
3¼	7	1⅝	583·208	4·0500	3	1¼	9	9	1089·79	7·5671
3½	7	2⅜	593·958	4·1241	3	1½	9	9⅞	1104·46	7·6691
3¾	7	3⅛	604·807	4·2000	3	1¾	9	10½	1119·24	7·7791
4	7	3⅞	615·753	4·2760	3	2	9	11⅜	1134·12	7·8681
4¼	7	4¾	626·798	4·3521	3	2¼	10	0⅛	1149·09	7·9791
4½	7	5½	637·941	4·4302	3	2½	10	0⅞	1164·16	8·0846
4¾	7	6¼	649·182	4·5083	3	2¾	10	1¾	1179·32	8·1891
5	7	7	660·521	4·5861	3	3	10	2½	1194·59	8·2951
5¼	7	7⅞	671·958	4·6665	3	3¼	10	3¼	1209·95	8·4026
5½	7	8⅝	683·494	4·7467	3	3½	10	4	1225·42	8·5091
5¾	7	9½	695·128	4·8274	3	3¾	10	4⅞	1240·98	8·6171
6	7	10¼	706·860	4·9081	3	4	10	5⅝	1256·64	8·7269
6¼	7	11	718·690	4·9901	3	4¼	10	6⅜	1272·39	8·8361
6½	7	11¾	730·618	5·0731	3	4½	10	7¼	1288·25	8·9462
6¾	8	0⅝	742·644	5·1573	3	4¾	10	8	1304·20	9·0561
7	8	1⅜	754·769	5·2278	3	5	10	8¾	1320·25	9·1686
7¼	8	2⅛	766·992	5·3264	3	5¼	10	9½	1336·40	9·2112
7½	8	2⅞	779·313	5·4112	3	5½	10	10⅜	1352·65	9·3936
7¾	8	3¾	791·732	5·4982	3	5¾	10	11⅛	1369·00	9·5061
8	8	4½	804·249	5·5850	3	6	10	11⅞	1385·44	9·6212
8¼	8	5⅜	816·865	5·6729	3	6¼	11	0¾	1401·98	9·7364
8½	8	6⅛	829·578	5·7601	3	6½	11	1½	1418·62	9·8518
8¾	8	6⅞	842·390	5·8491	3	6¾	11	2¼	1435·36	9·9671
9	8	7⅝	855·300	5·9398	3	7	11	3	1452·20	10·084
9¼	8	8½	868·308	6·0291	3	7¼	11	3⅞	1469·14	10·202
9½	8	9¼	881·415	6·1201	3	7½	11	4⅝	1486·17	10·320
9¾	8	10	894·619	6·2129	3	7¾	11	5⅜	1503·30	10·439

Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
3	8	11	6¼	1520·53	10·559	4	6	14	1⅝	2290·22	15·904
3	8¼	11	7	1537·86	10·679	4	6¼	14	2⅜	2311·48	16·051
3	8½	11	7¾	1555·28	10·800	4	6½	14	3¼	2332·83	16·200
3	8¾	11	8½	1572·81	10·922	4	6¾	14	4	2354·28	16·349
3	9	11	9⅜	1590·43	11·044	4	7	14	4¾	2375·83	16·498
3	9¼	11	10⅛	1608·15	11·167	4	7¼	14	5½	2397·48	16·649
3	9½	11	10⅞	1625·97	11·291	4	7½	14	6⅜	2419·22	16·800
3	9¾	11	11¾	1643·89	11·415	4	7¾	14	7⅛	2441·07	16·951
3	10	12	0½	1661·90	11·534	4	8	14	7⅞	2463·01	17·104
3	10¼	12	1¼	1680·02	11·666	4	8¼	14	8⅝	2485·05	17·257
3	10½	12	2	1698·23	11·793	4	8½	14	9½	2507·19	17·411
3	10¾	12	2⅞	1716·54	11·920	4	8¾	14	10¼	2529·42	17·565
3	11	12	3⅝	1734·94	12·048	4	9	14	11	2551·76	17·720
3	11¼	12	4⅜	1753·45	12·176	4	9¼	14	11⅞	2574·19	17·876
3	11½	12	5¼	1772·05	12·305	4	9½	15	0⅝	2596·72	18·033
3	11¾	12	6	1790·76	12·435	4	9¾	15	1⅜	2619·35	18·189
4	0	12	6¾	1809·56	12·566	4	10	15	2¼	2642·08.	18·347
4	0¼	12	7½	1828·46	12·697	4	10¼	15	2⅞	2664·91	18·506
4	0½	12	8⅜	1847·45	12·829	4	10½	15	3¾	·2687·83	18·665
4	0¾	12	9⅛	1866·55	12·962	4	10¾	15	4½	2710·85	18·825
4	1	12	9⅞	1885·74	13·095	4	11	15	5¼	2733·97	18·985
4	1¼	12	10¾	1905·03	13·229	4	11¼	15	6⅛	2757·19	19·147
4	1½	12	11½	1924·42	13·364	4	11½	15	6⅞	2780·51	19·309
4	1¾	13	0¼	1943·91	13·499	4	11¾	15	7¾	2803·92	19·471
4	2	13	1	1963·50	13·635	5	0	15	8½	2827·44	19·635
4	2¼	13	1⅞	1983·18	13·772	5	0¼	15	9¼	2851·05	19·798
4	2½	13	2⅝	2002·96	13·909	5	0½	15	10	2874·76	19·963
4	2¾	13	3⅜	2022·84	14·047	5	0¾	15	10¾	2898·56	20·128
4	3	13	4¼	2042·82	14·186	5	1	15	11⅝	2922·47	20·294
4	3¼	13	5	2062·90	14·325	5	1¼	16	0⅜	2946·47	20·461
4	3½	13	5¾	2083·07	14·465	5	1½	16	1¼	2970·57	20·629
4	3¾	13	6½	2103·35	14·606	5	1¾	16	1⅞	2994·77	20·797
4	4	13	7⅜	2123·72	14·748	5	2	16	2¾	3019·07	20·965
4	4¼	13	8⅛	2144·19	14·890	5	2¼	16	3½	3043·47	21·135
4	4½	13	8⅞	2164·75	15·033	5	2½	16	4¼	3067·96	21·305
4	4¾	13	9¾	2185·42	15·176	5	2¾	16	5⅛	3092·56	21·476
4	5	13	10½	2206·18	15·320	5	3	16	5⅞	3117·25	21·647
4	5¼	13	11¼	2227·05	15·465	5	3¼	16	6¼	3142·04	21·819
4	5½	14	0	2248·01	15·611	5	3½	16	7½	3166·92	21·992
4	5¾	14	0⅞	2269·06	15·757	5	3¾	16	8¼	3191·91	22·166

Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
5	4	16	9	3216·99	22·333	6	2	19	4½	4300·85	29·867
5	4¼	16	9¾	3242·17	22·515	6	2¼	19	5¼	4329·95	30·069
5	4½	16	10⅝	3267·46	22·621	6	2½	19	6	4359·16	30·271
5	4¾	16	11⅜	3292·83	22·866	6	2¾	19	6¾	4388·47	30·475
5	5	17	0⅛	3318·31	23·043	6	3	19	7⅝	4417·87	30·679
5	5¼	17	0⅞	3343·88	23·221	6	3¼	19	8⅜	4447·37	30·884
5	5½	17	1¾	3369·56	23·330	6	3½	19	9⅛	4476·97	31·090
5	5¾	17	2½	3395·33	23·578	6	3¾	19	9⅞	4506·67	31·296
5	6	17	3⅜	3421·20	23·758	6	4	19	10¾	4536·47	31·503
5	6¼	17	4⅛	3447·16	23·938	6	4¼	19	11½	4566·36	31·710
5	6½	17	4⅞	3473·23	24·119	6	4½	20	0¼	4596·35	31·919
5	6¾	17	5⅝	3499·39	24·301	6	4¾	20	1⅛	4626·44	32·114
5	7	17	6½	3525·66	24·483	6	5	20	1⅞	4656·63	32·337
5	7¼	17	7¼	3552·01	24·666	6	5¼	20	2⅝	4686·92	32·548
5	7½	17	8	3578·47	24·850	6	5½	20	3½	4717·30	32·759
5	7¾	17	8¾	3605·03	25·034	6	5¾	20	4¼	4747·79	32·970
5	8	17	9⅝	3631·68	25·220	6	6	20	5	4778·37	33·183
5	8¼	17	10⅜	3658·44	25·405	6	6¼	20	5¾	4809·05	33·396
5	8½	17	11⅛	3685·29	25·592	6	6½	20	6½	4839·83	33·619
5	8¾	17	11⅞	3712·24	25·779	6	6¾	20	7⅜	4870·70	33·824
5	9	18	0¾	3739·28	25·964	6	7	20	8⅛	4901·68	34·039
5	9¼	18	1½	3766·43	26·155	6	7¼	20	8⅞	4932·75	34·255
5	9½	18	2¼	3793·67	26·344	6	7½	20	9¾	4963·92	34·471
5	9¾	18	3⅛	3821·02	26·534	6	7¾	20	10½	4995·19	34·688
5	10	18	3⅞	3848·46	26·725	6	8	20	11¼	5026·26	34·906
5	10¼	18	4⅝	3875·99	26·916	6	8¼	21	0⅛	5058·02	35·125
5	10½	18	5½	3903·63	27·108	6	8½	21	0⅞	5089·58	35·344
5	10¾	18	6¼	3931·36	27·301	6	8¾	21	1⅝	5121·24	35·564
5	11	18	7	3959·20	27·494	6	9	21	2⅜	5153·00	35·784
5	11¼	18	7¾	3987·13	27·688	6	9¼	21	3¼	5184·86	36·006
5	11½	18	8⅝	4015·16	27·883	6	9½	21	4	5216·82	36·227
5	11¾	18	9⅜	4043·28	28·078	6	9¾	21	4¾	5248·87	36·450
6	0	18	10⅛	4071·51	28·274	6	10	21	5½	5281·02	36·674
6	0¼	18	10⅞	4099·83	28·471	6	10¼	21	6⅜	5313·27	36·897
6	0½	18	11¾	4128·25	28·668	6	10½	21	7⅛	5345·62	37·122
6	0¾	19	0½	4156·77	28·866	6	10¾	21	7⅞	5378·07	37·347
6	1	19	1¼	4185·39	29·065	6	11	21	8¾	5410·62	37·573
6	1¼	19	2⅛	4214·11	29·264	6	11¼	21	9½	5443·26	37·700
6	1½	19	2⅞	4242·92	29·466	6	11½	21	10¼	5476·00	38·027
6	1¾	19	3⅝	4271·83	29·665	6	11¾	21	11	5508·84	38·256

Dia. in ft. & in.		Circum. in ft. and in.		Area in feet.	Dia. in ft. & in.		Circum. in ft. and in.	
7	0	21	11⅞	38·4846	10	0	31	5
	1	22	3	39·4060		1	31	8⅛
	2	22	6⅛	40·3388		2	31	11¼
	3	22	9¼	41·2825		3	32	2⅜
	4	23	0½	42·2367		4	32	5½
	5	23	2½	43·2022		5	32	8⅝
	6	23	6¾	44·1787		6	32	11¾
	7	23	11	45·1656		7	33	2⅞
	8	24	1⅛	46·1638		8	33	6⅛
	9	24	4⅛	47·1730		9	33	9¼
	10	24	7¼	48·1926		10	34	0⅜
	11	24	10½	49·2236		11	34	3½
8	0	25	1½	50·2656	11	0	34	6⅝
	1	25	4⅝	51·3178		1	34	9¾
	2	25	7⅞	52·3816		2	35	0⅞
	3	25	11	53·4562		3	35	4⅛
	4	26	2⅛	54·5412		4	35	7¼
	5	26	5¼	55·6377		5	35	10⅝
	6	26	8⅜	56·7451		6	36	1½
	7	26	11½	57·8628		7	36	4½
	8	27	2¾	58·9920		8	36	7¾
	9	27	5¾	60·1321		9	36	10⅞
	10	27	9	61·2826		10	37	2¾
	11	28	0⅛	62·4445		11	37	5¼
9	0	28	3¼	63·6174	12	0	37	8⅜
	1	28	6⅜	64·8006		1	37	11½
	2	28	9½	65·9951		2	38	2⅝
	3	29	0⅝	67·2007		3	38	5¾
	4	29	3¾	68·4166		4	38	8⅞
	5	29	7	69·6440		5	39	0
	6	29	10⅛	70·8823		6	39	3¼
	7	30	1¼	72·1309		7	39	6⅜
	8	30	4⅜	73·3910		8	39	9½
	9	30	7½	74·6620		9	40	0⅝
	10	30	11⅜	75·9433		10	40	3¾
	11	31	1¾	77·2362		11	40	6⅞

No.	S. R.	C. R.	No.	S. R.	C. R.	No.	S. R.	C. R.
1	1·0000	1·0000	55	7·4161	3·8029	109	10·4403	4·7768
2	1·4142	1·2599	56	7·4833	3·8258	110	10·4880	4·7914
3	1·7320	1·4422	57	7·5498	3·8485	111	10·5356	4·8058
4	2·0000	1·5874	58	7·6157	3·8708	112	10·5830	4·8202
5	2·2360	1·7099	59	7·6811	3·8929	113	10·6301	4·8345
6	2·4494	1·8171	60	7·7459	3·9148	114	10·6770	4·8488
7	2·6457	1·9129	61	7·8102	3·9364	115	10·7238	4·8629
8	2·8284	2·0000	62	7·8740	3·9578	116	10·7703	4·8769
9	3·0000	2·0800	63	7·9372	3·9790	117	10·8166	4·8909
10	3·1622	2·1544	64	8·0000	4·0000	118	10·8627	4·9048
11	3·3166	2·2239	65	8·0622	4·0207	119	10·9087	4·9186
12	3·4641	2·2894	66	8·1240	4·0412	120	10·9544	4·9324
13	3·6055	2·3513	67	8·1853	4·0615	121	11·0000	4·9460
14	3·7416	2·4101	68	8·2462	4·0816	122	11·0453	4·9596
15	3·8729	2·4662	69	8·3066	4·1015	123	11·0905	4·9731
16	4·0000	2·5198	70	8·3666	4·1212	124	11·1355	4·9866
17	4·1231	2·5712	71	8·4261	4·1408	125	11·1803	5·0000
18	4·2426	2·6207	72	8·4852	4·1601	126	11·2249	5·0132
19	4·3588	2·6684	73	8·5440	4·1793	127	11·2694	5·0265
20	4·4721	2·7144	74	8·6023	4·1983	128	11·3137	5·0396
21	4·5825	2·7589	75	8·6602	4·2171	129	11·3578	5·0527
22	4·6904	2·8020	76	8·7177	4·2358	130	11·4017	5·0657
23	4·7958	2·8438	77	8·7749	4·2543	131	11·4455	5·0787
24	4·8989	2·8844	78	8·8317	4·2726	132	11·4891	5·0916
25	5·0000	2·9240	79	8·8881	4·2908	133	11·5325	5·1044
26	5·0990	2·9624	80	8·9442	4·3088	134	11·5758	5·1172
27	5·1961	3·0000	81	9·0000	4·3267	135	11·6189	5·1299
28	5·2915	3·0365	82	9·0553	4·3444	136	11·6619	5·1425
29	5·3851	3·0723	83	9·1104	4·3620	137	11·7046	5·1551
30	5·4772	3·1072	84	9·1651	4·3795	138	11·7473	5·1676
31	5·5677	3·1413	85	9·2195	4·3968	139	11·7898	5·1801
32	5·6568	3·1748	86	9·2736	4·4140	140	11·8321	5·1924
33	5·7445	3·2075	87	9·3273	4·4310	141	11·8743	5·2048
34	5·8309	3·2396	88	9·3808	4·4479	142	11·9163	5·2171
35	5·9160	3·2710	89	9·4339	4·4647	143	11·9582	5·2293
36	6·0000	3·3019	90	9·4868	4·4814	144	12·0000	5·2414
37	6·0827	3·3322	91	9·5393	4·4979	145	12·0415	5·2535
38	6·1644	3·3619	92	9·5916	4·5143	146	12·0830	5·2656
39	6·2449	3·3912	93	9·6436	4·5306	147	12·1243	5·2776
40	6·3245	3·4199	94	9·6953	4·5468	148	12·1655	5·2895
41	6·4031	3·4482	95	9·7467	4·5629	149	12·2065	5·3014
42	6·4807	3·4760	96	9·7979	4·5788	150	12·2474	5·3132
43	6·5574	3·5033	97	9·8488	4·5947	151	12·2882	5·3250
44	6·6332	3·5303	98	9·8994	4·6104	152	12·3288	5·3368
45	6·7082	3·5568	99	9·9498	4·6260	153	12·3693	5·3484
46	6·7823	3·5830	100	10·0000	4·6415	154	12·4096	5·3601
47	6·8556	3·6088	101	10·0498	4·6570	155	12·4498	5·3716
48	6·9282	3·6342	102	10·0995	4·6723	156	12·4899	5·3832
49	7·0000	3·6593	103	10·1488	4·6875	157	12·5299	5·3946
50	7·0710	3·6840	104	10·1980	4·7026	158	12·5698	5·4061
51	7·1414	3·7084	105	10·2469	4·7176	159	12·6095	5·4175
52	7·2111	3·7325	106	10·2956	4·7326	160	12·6491	5·4288
53	7·2801	3·7562	107	10·3440	4·7474	161	12·6885	5·4401
54	7·3484	3·7797	108	10·3923	4·7622	162	12·7279	5·4513

To find the square or cube root of a number consisting of integers and decimals.—Rule. Multiply the difference between the root of the integer part of the given number, and the root of the next higher number, by the decimal part of the given number, and add the product to the root of the given integer number; the sum is the root required.

Ex. Required the square root of 20·321.

Square root of 21 = 4·5825
Do. 20 = 4·4721
Diff. = ·1104 × ·321 + 4·4721 = 4·507, &c., the root required.

PER-CENTAGE AND DISCOUNT TABLE.

Rate per cent.	Rate per £. in shillings.	Rate per s. in pence.	Rate per cent.	Rate per £. in shillings.	Rate per s. in pence.
⅛	·025	·015	5½	1·1	·66
¼	·05	·03	6	1·2	·72
½	·1	·06	6¼	1·25	·75
¾	·15	·09	7½	1·5	·9
1	·2	·12	8¾	1·75	1·05
2	·4	·24	10	2	1·2
2½	·5	·3	12½	2·5	1·5
3	·6	·36	15	3	1·8
3½	·7	·42	20	4	2·4
4	·8	·48	25	5	3
4½	·9	·54	30	6	3·6
5	1	·6	40	8	4·8

To cover a discount of	Mult. the net price by	Divide the product by	To cover a discount of	Mult. the net price by	Divide the product by
5 p. ct.	20	19	27½ p.ct.	40	29
7½	40	37	30	10	7
10	10	9	32½	40	27
12½	8	7	35	20	13
15	20	17	37½	8	5
17½	40	33	40	5	3
20	5	4	42½	40	23
22½	40	31	45	20	11
25	4	3	47½	40	21

For 50 per cent., double the sum.

Ex. 1. Required the per-centage on £127 at 3½ per·cent.

127 × ·7 = 88·9 shillings, or £4. 8*s*. 10¾*d*.

Ex. 2. What is the per-centage on 36 shillings at 2½ per cent.?

36 × ·3 = 10·8 pence, or 10 pence and 3 farthings nearly.